

Radar/Storm Interpretation

Thunderstorm Spectrum



Minimal
Threat (?)

Moderate
Threat

Moderate
Threat

High Threat
Mesocyclone Present

Severe Storm Generalities

Evaluate the distribution of echoes on the radar display because certain organized patterns contain “hot spots” where the likelihood of severe storm development is the most favorable. These areas include:

- The cell at the southern end of a squall line
- Large, intense, isolated echoes
- Isolated cell ahead of a squall line
- Cells in a broken squall line, especially those just north of a gap in the line
- Cells whose motion deviates from the mean storm motion, “Right Movers”
- Cells near a wave in a squall line (LEWP), if such a wave is a reflection of an intense mesoscale pressure system

Severe Storm Generalities

The most severe, organized storms occur in environments where the shear and thermal instability are both moderate or strong and well balanced.

Supercells seem to be the favored mode of convection when the low-level, storm relative winds are greater than 19 knots and veer by roughly 90° in the lowest 4 km.

A Non-Severe Schematic

Large CAPE and weak Shear produce a more upright thunderstorm.

Precipitation loading in the updraft keeps this type of storm from reaching severe levels

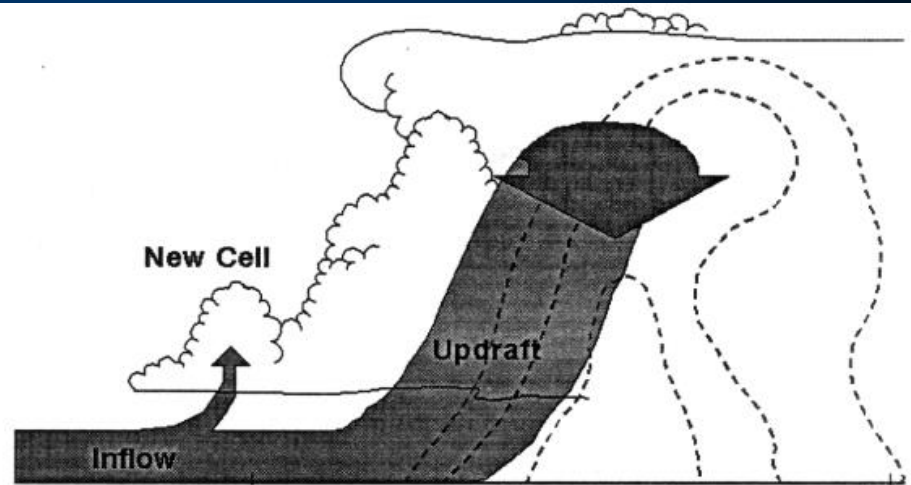
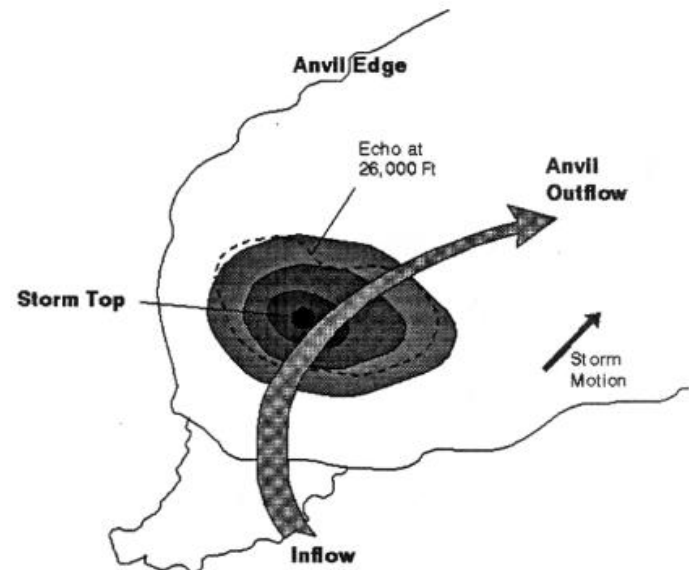


Figure 6-38. Schematic diagram of a vertical cross section or Range Height Indicator (RHI) radar display of a thunderstorm with the low-level inflow, a moderate updraft, and outflow aloft (solid lines) superimposed. Radar reflectivity (dashed lines) with reflectivities greater than 50 dBZ stippled.



Severe Storm Generalities

Les Lemon Technique - Severe Thunderstorm Warning Criteria Guidelines

Issue warning if:

- 50 dbz return at 27kft AGL or higher

Or if all of the following are satisfied:

- Mid level (16-39kft AGL) return >45 dbz
- Mid level overhang > 3.2 nmi beyond the strong low level reflectivity gradient
- Highest echo top located over the strong low level reflectivity gradient

A leaning “tower”, due to shear in the environment, will carry precipitation away from the updraft of well-organized storms. This diminishes the potential for significant water loading.

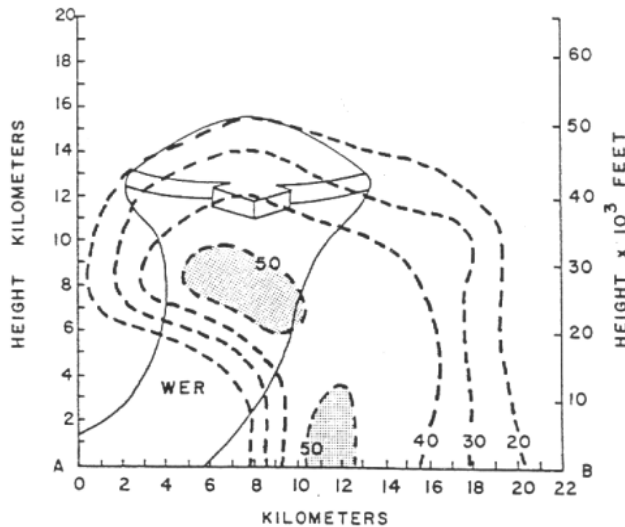


Figure 2a. Same as Figure 1a, except that the updraft is strong. The WER is the weak echo region.

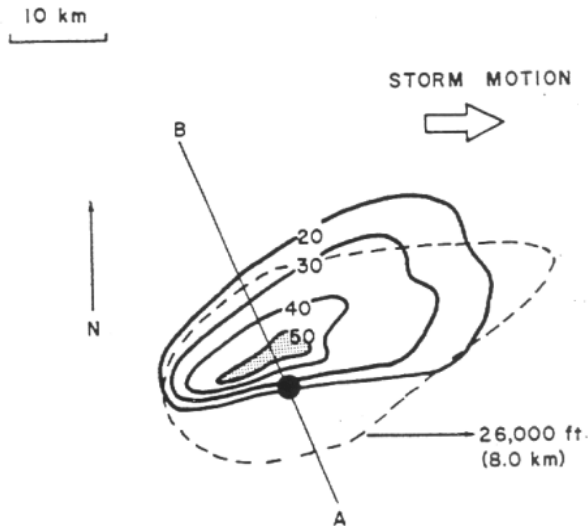


Figure 2b. Same as Figure 1b, except line AB corresponds to the cross-section in Figure 2a.

Severe Storm Generalities

Les Lemon Technique - Tornado Warning Criteria Guidelines

Issue warning if:

All of the follow three are satisfied:

- Mid level (16-39kft AGL) return >45 dbz
- Mid level overhang > 3.2 nmi beyond the strong low level reflectivity gradient
- Highest echo top located over the strong low level reflectivity gradient, or shifted farther towards the mid level overhang.

And either or both of the following are present:

- Low level pendant i.e. hook is oriented at right angles to the storm motion. The pendant must lie beneath or bound the mid level overhang.
- A BWER is detected.

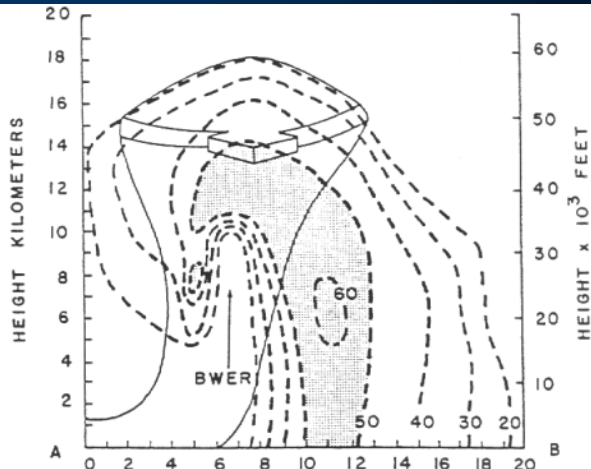


Figure 3a. Same as Figure 1a, except the updraft is intense.

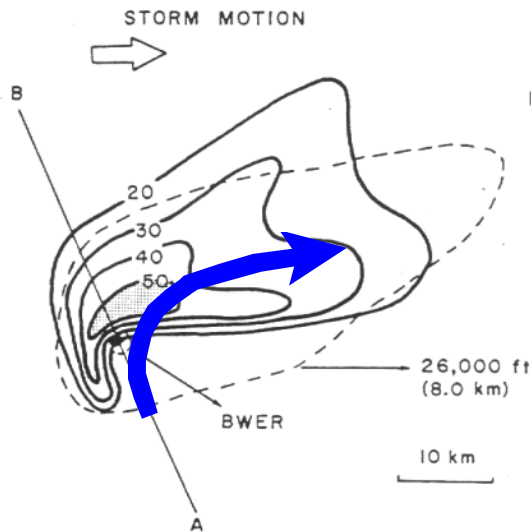


Figure 3b. Same as Figure 1b, except that the line AB is the cross-section axis of Figure 3a and the BWER is the location of the bounded weak echo region.

The Pulse Storm

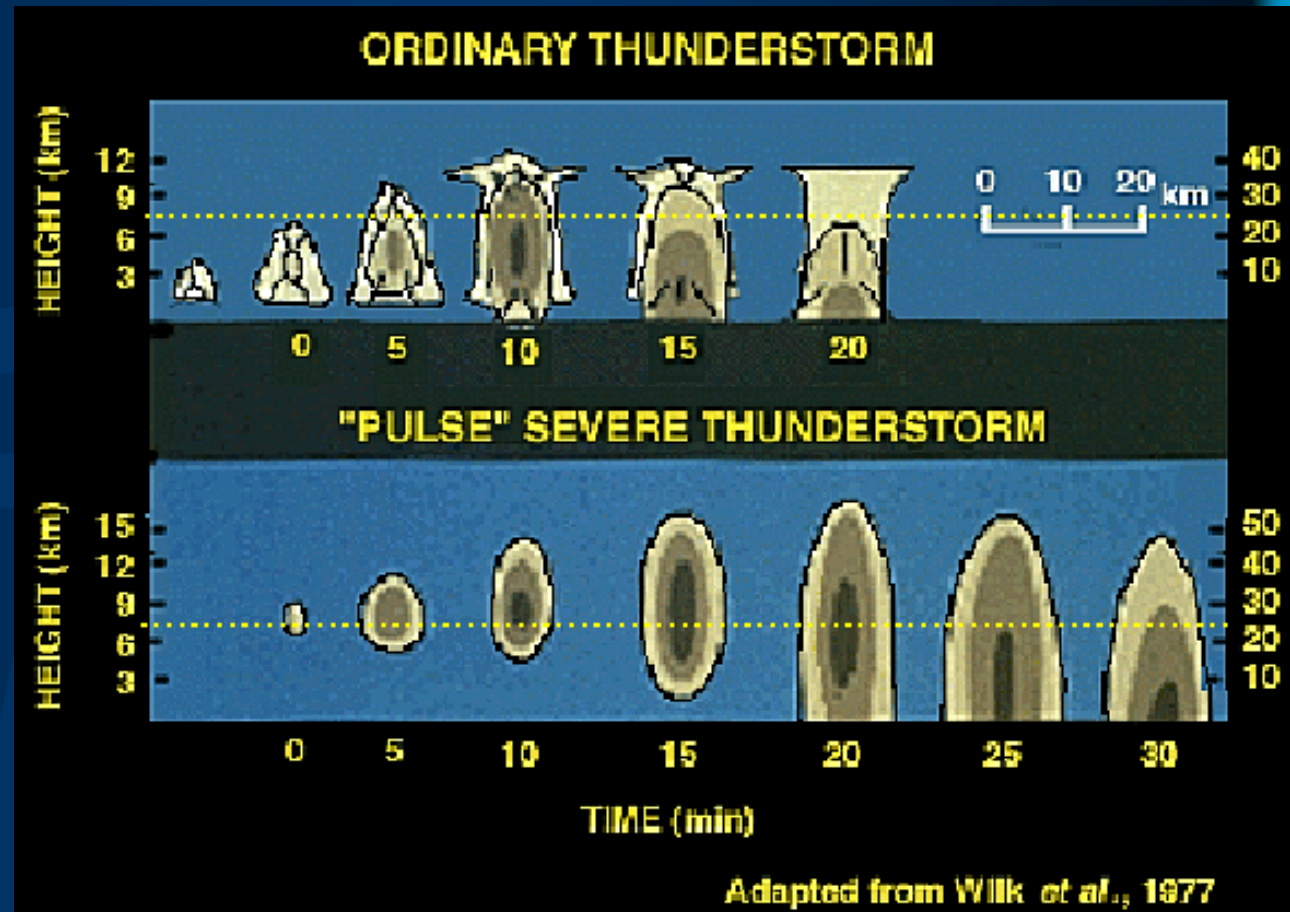
Rapid development and short lifespan make the **Pulse Storm** one of the hardest to warn for. Lead time on warnings is generally the shortest with these storms.

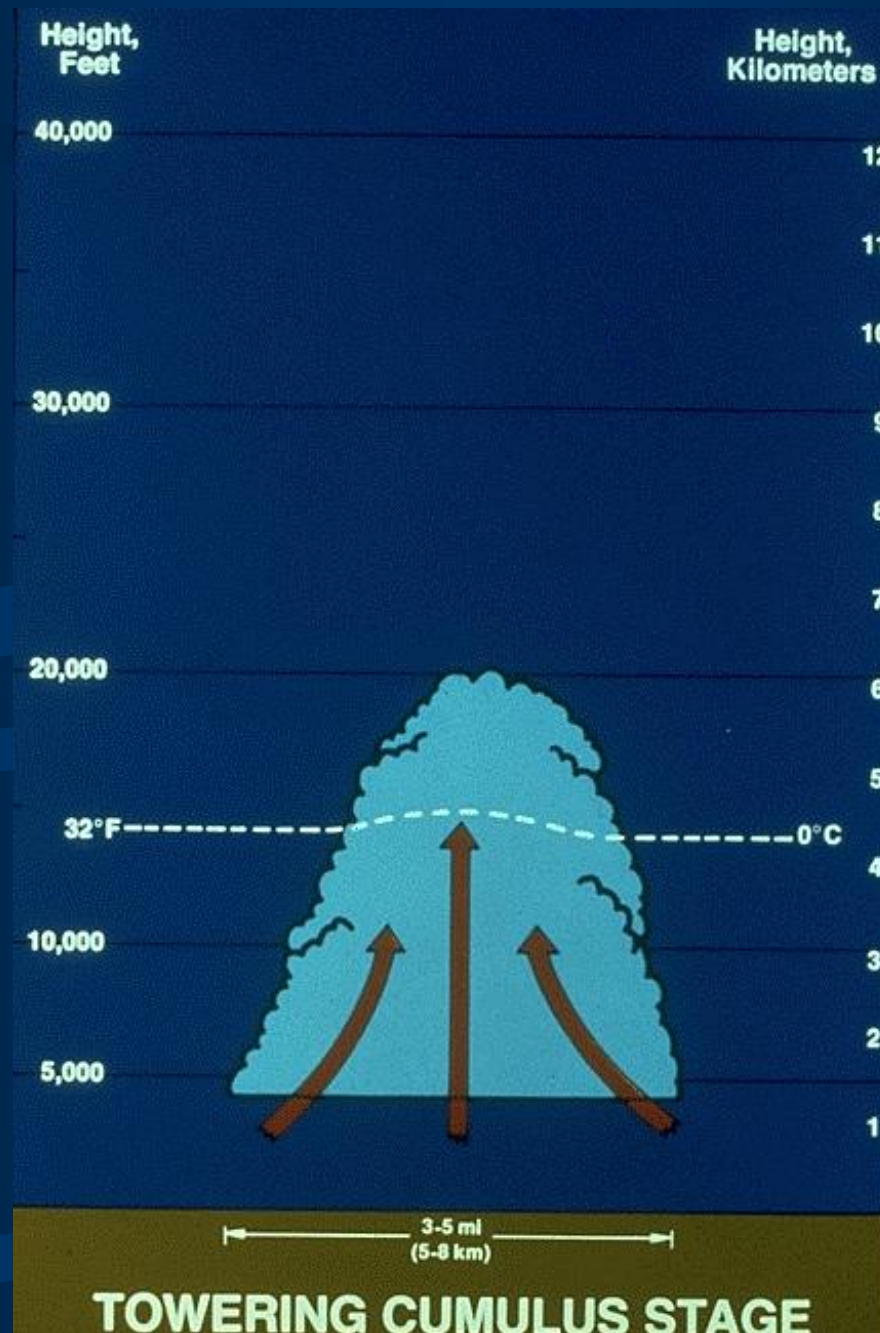
Main threat:

- * Brief period of hail. Usually an inch or less.
- * Brief downburst winds.
- * Possible weak tornadoes/landspouts

Pulse Storm Evolution

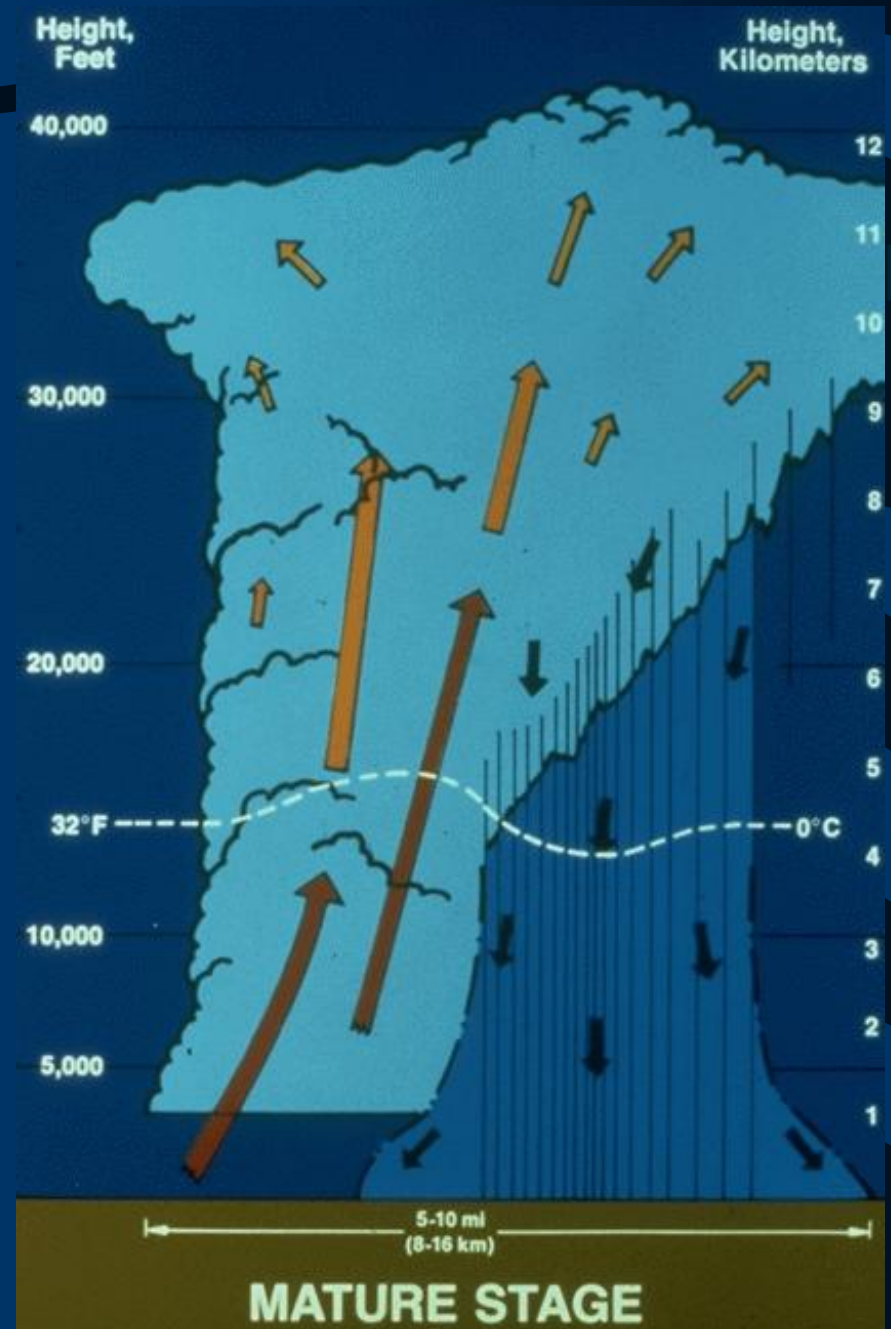
Note the weaker, lower elevation development and shorter lifespan of the ordinary thunderstorm, compared to the Pulse Severe Storm.



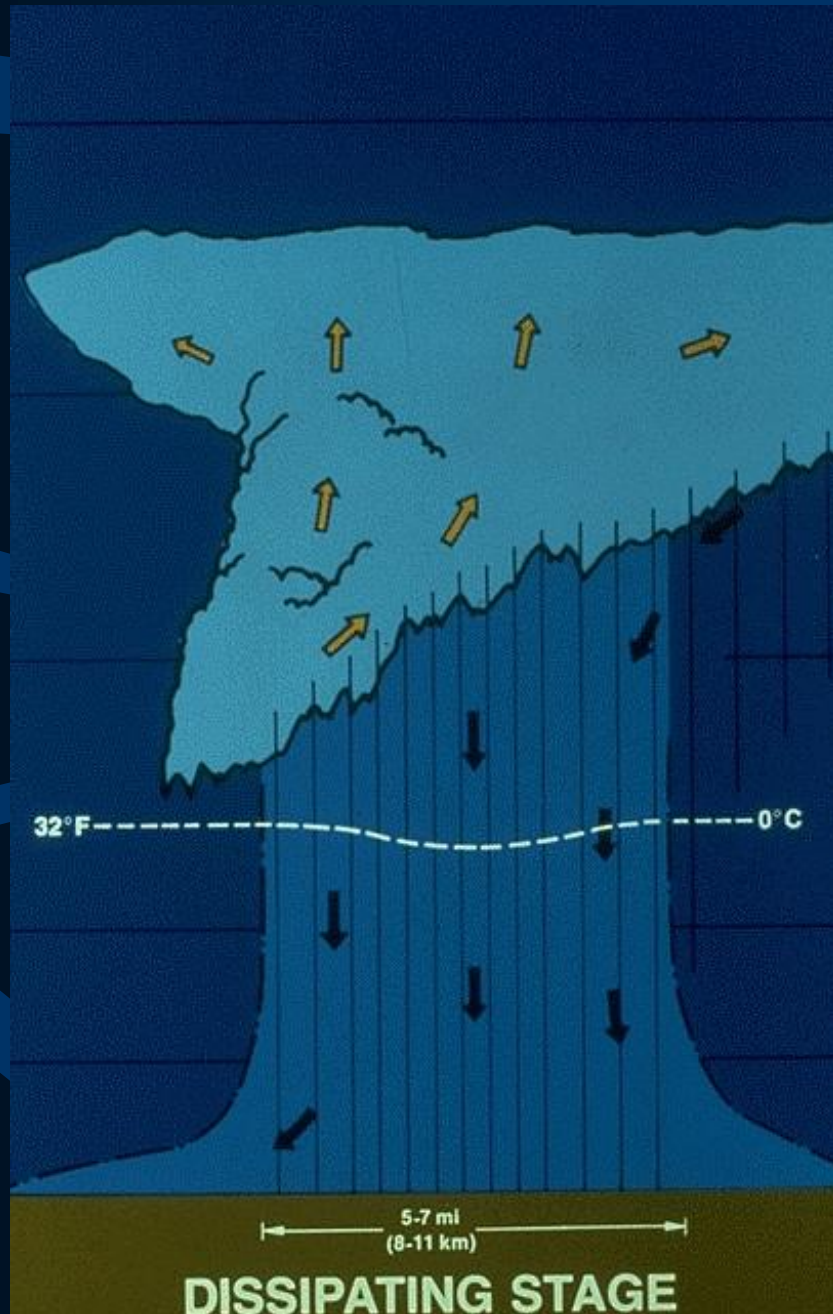




Slight lean to the tower keeps precipitation/downdraft from interfering with the updraft. This makes for a more efficient and potentially severe thunderstorm.







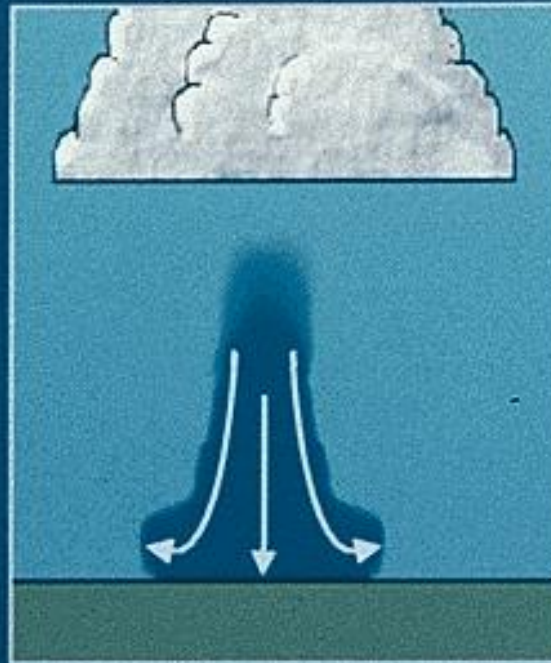
The dissipating stage of a Pulse Severe thunderstorm is the time when most severe weather occurs.

The dissipating stage may lead to...

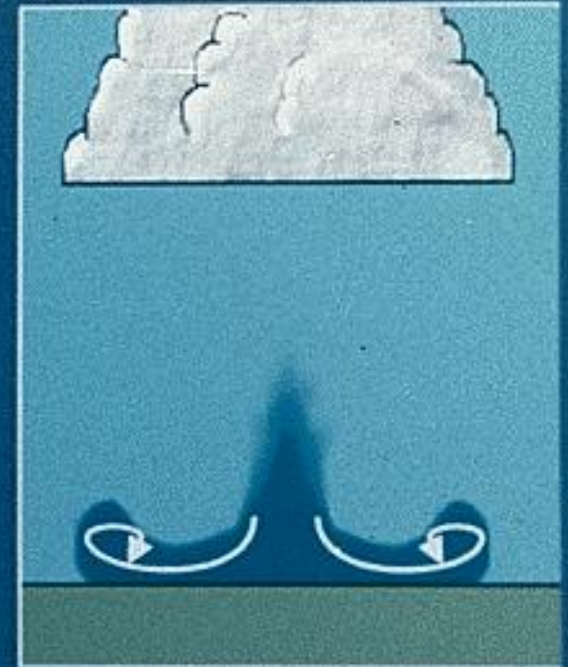
Downburst Life Cycle



FORMATION -
Evaporation and
precip. drag
forms downdraft



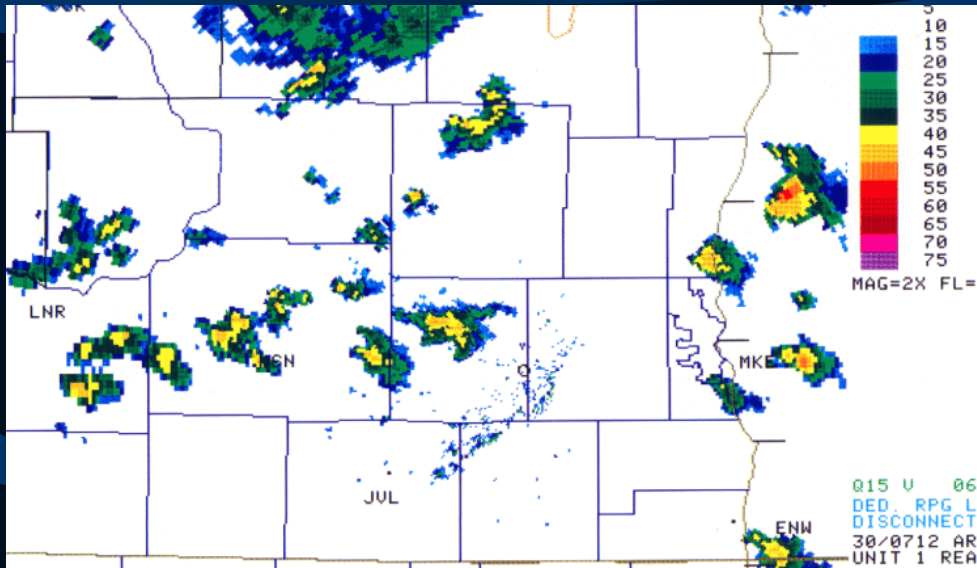
IMPACT -
Downdraft quickly
accelerates and
strikes ground



DISSIPATION -
Downburst moves
away from point
of impact



Pulse Storms on Radar



0.5° Slice

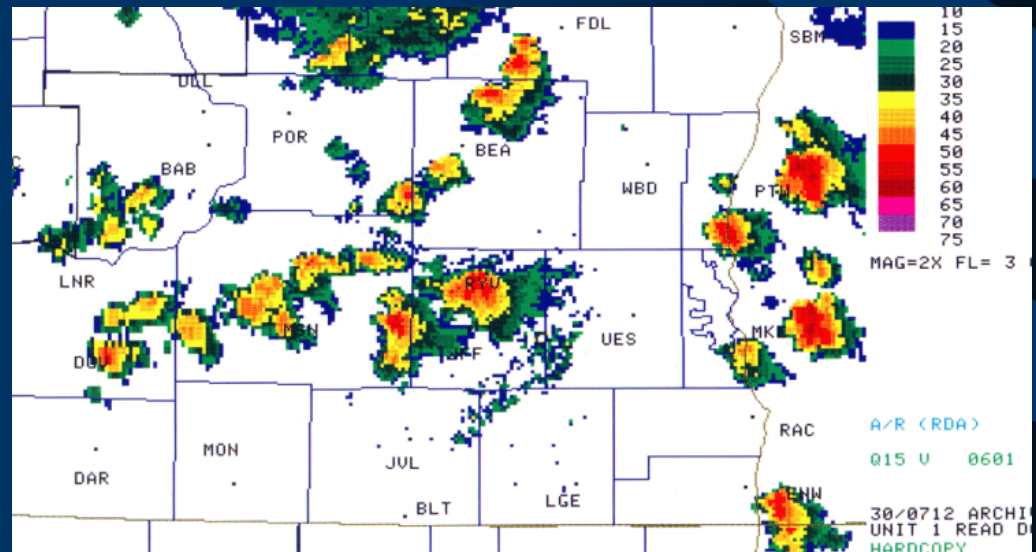
July 4, 1994 ~ 6:00 PM CDT
Multiple wind/hail events.

Composite
Refectivity

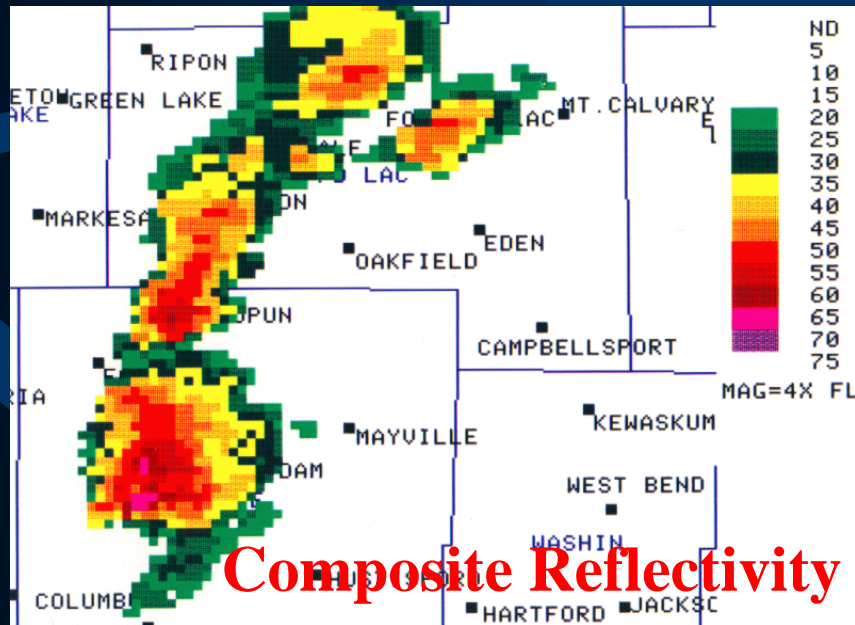
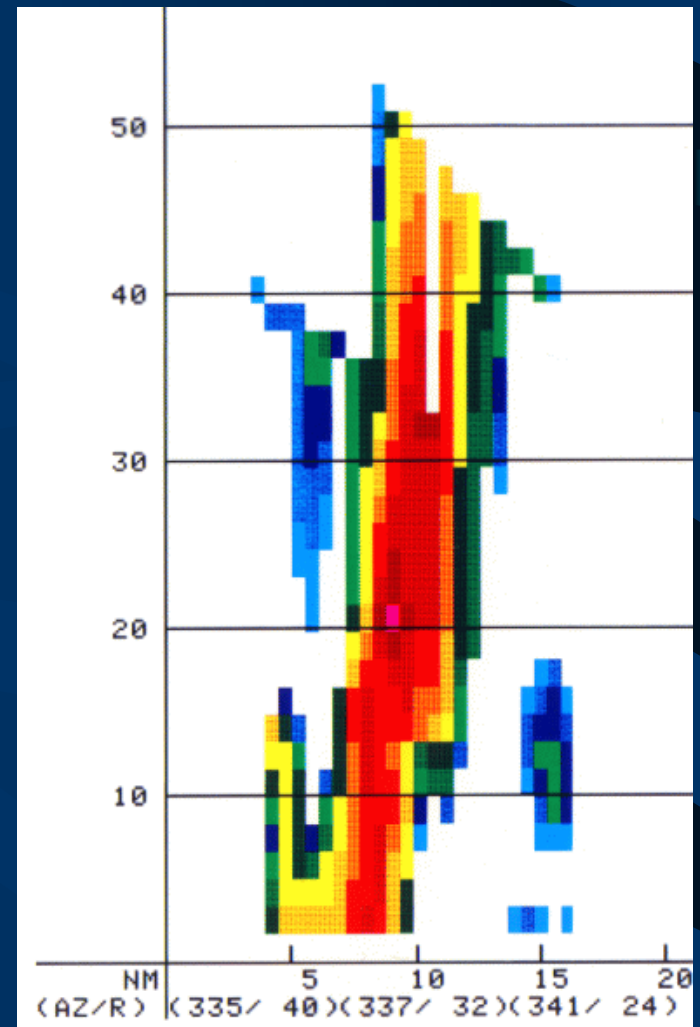
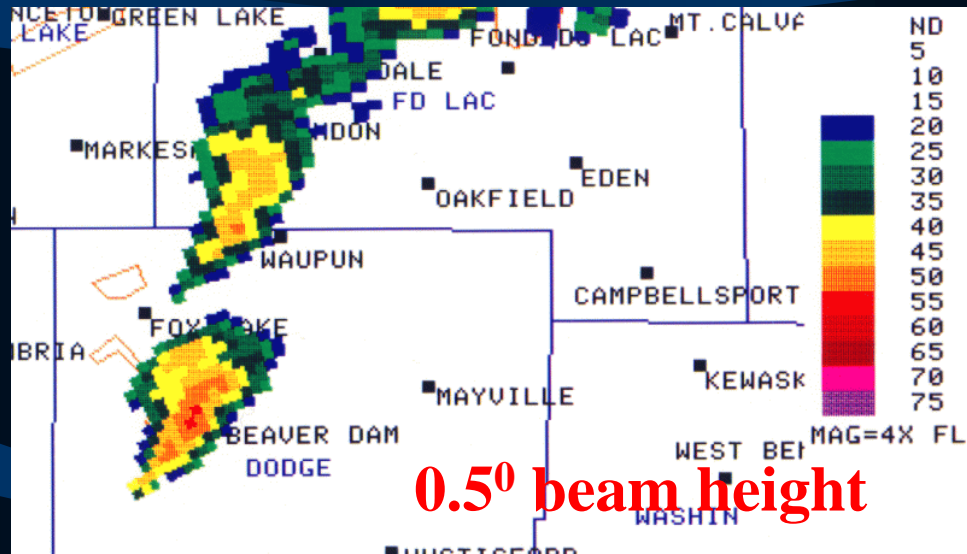
This can ruin a Radar
Operator's day...

Multiple, isolated pulse
storms require fast analysis
and decision making by the
radar operator.

Use **VIL** to weed out weaker
storms.



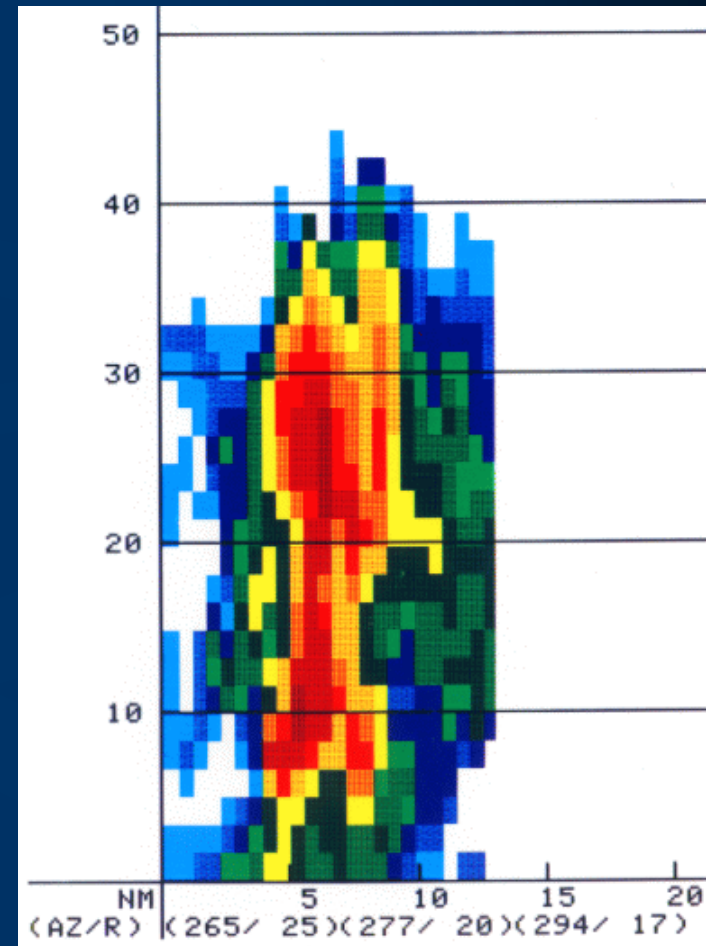
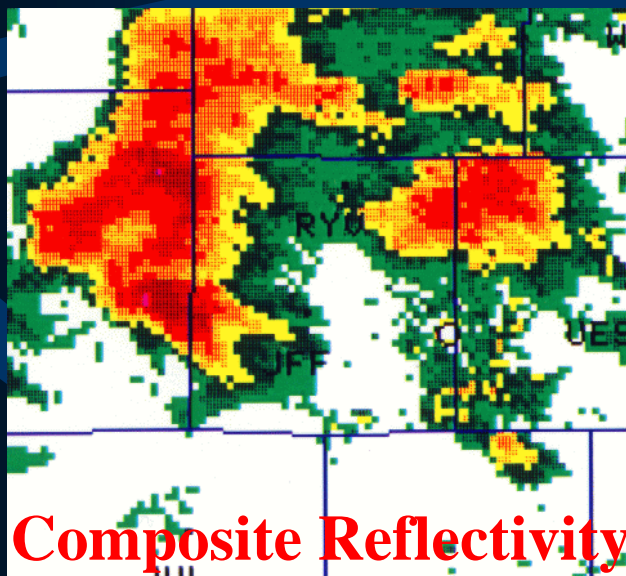
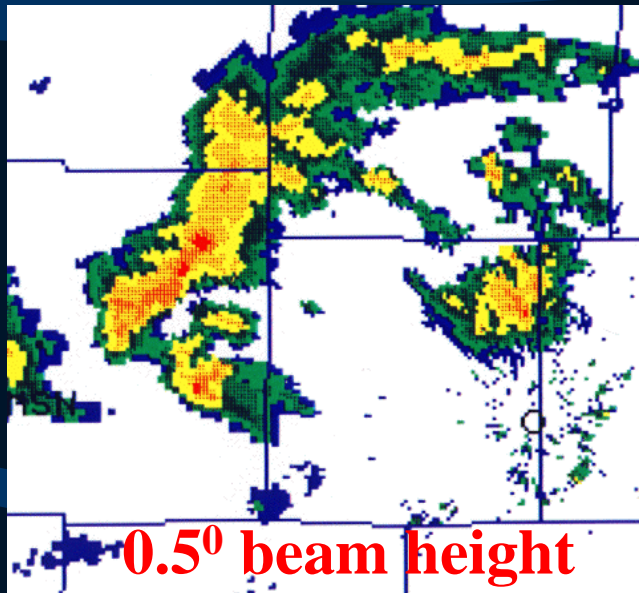
Pulse Storm Example



Note the leaning tower, tops around 50kft and max DBZ around 20kft.

This storm produced baseball size hail in Dodge County on 7/15/95

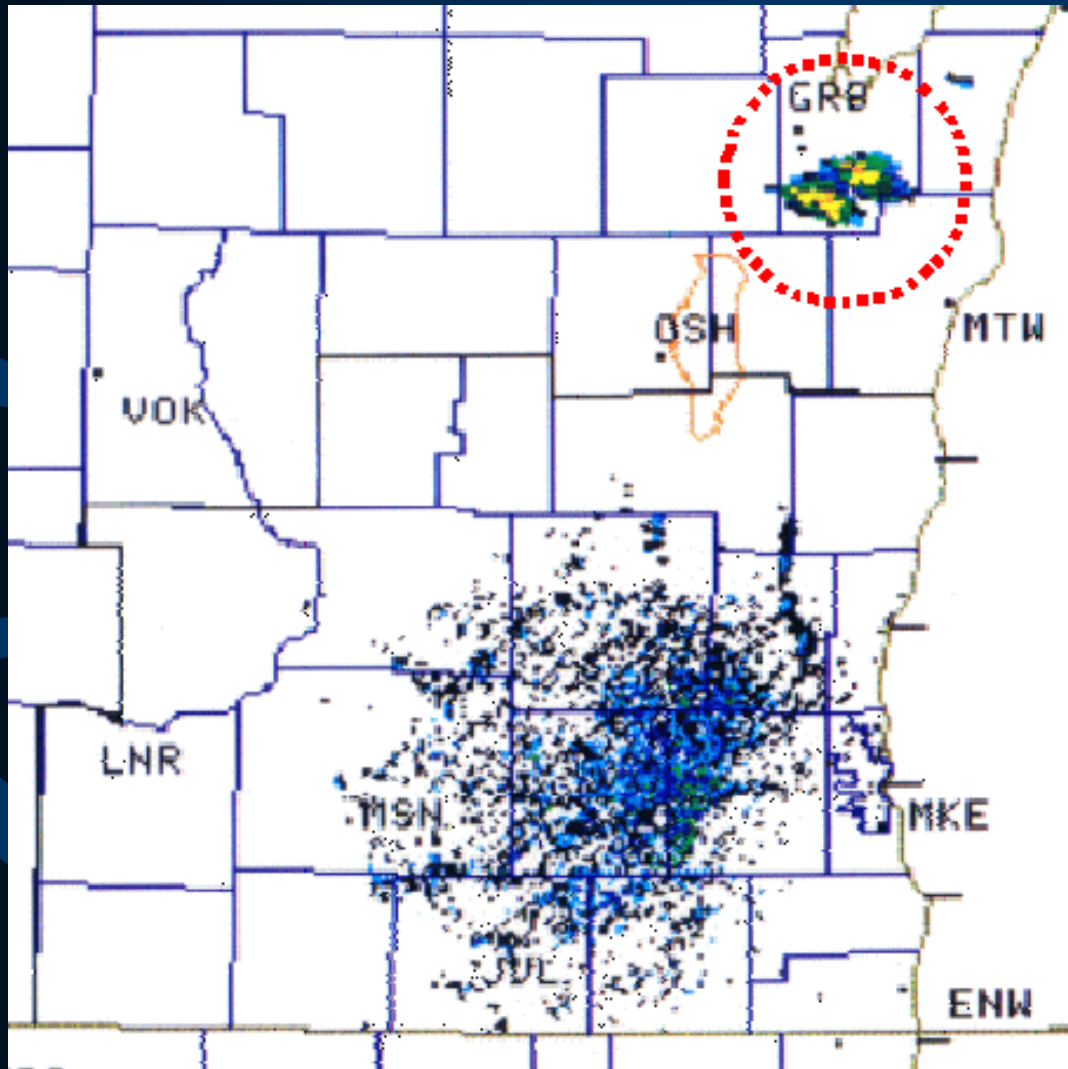
Pulse Storm Example



Note the leaning tower, tops around 45kft and max DBZ around 25kft.

This storm produced 2" hail in the city of Jefferson, Jefferson county, on 8/24/98

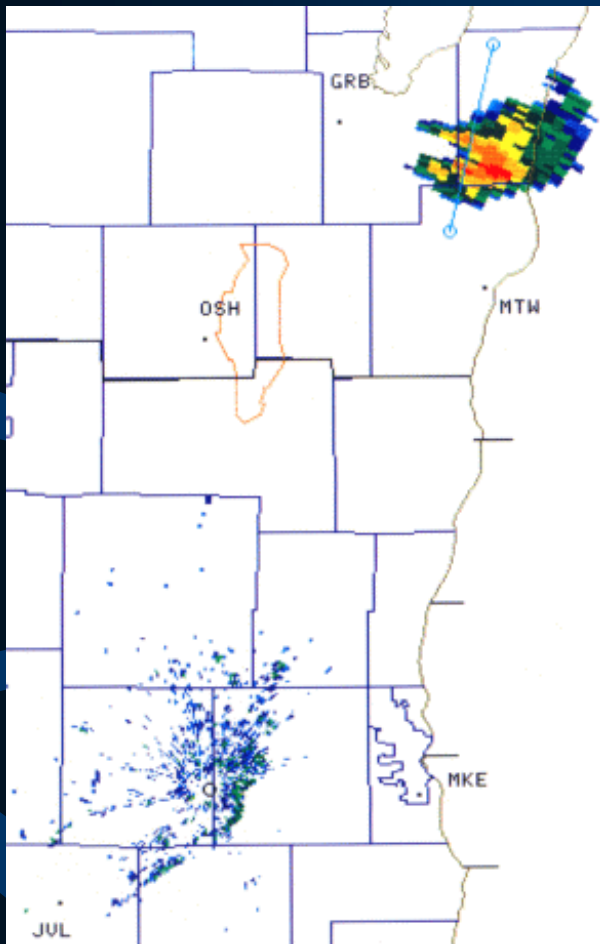
A Pulse Storm to Remember



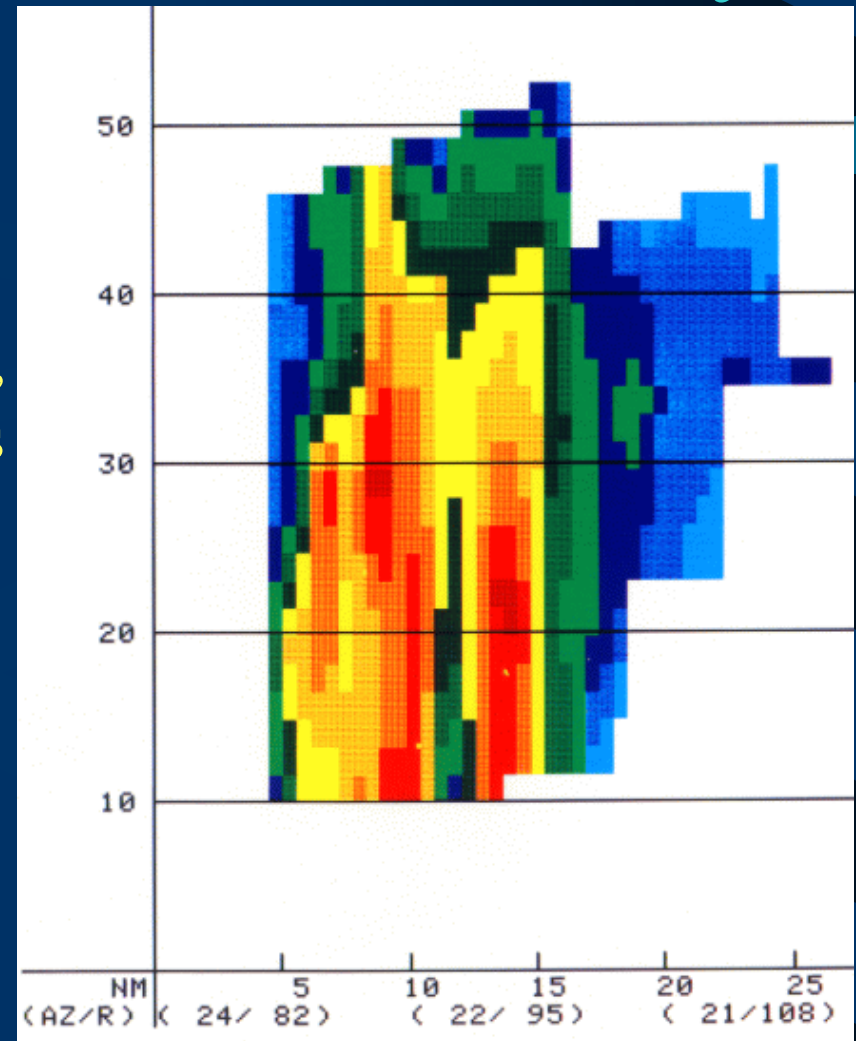
July 5, 1994 at 4:03 PM

An Isolated Thunderstorm
develops south of Green Bay.

Pulse Storm in Manitowoc County

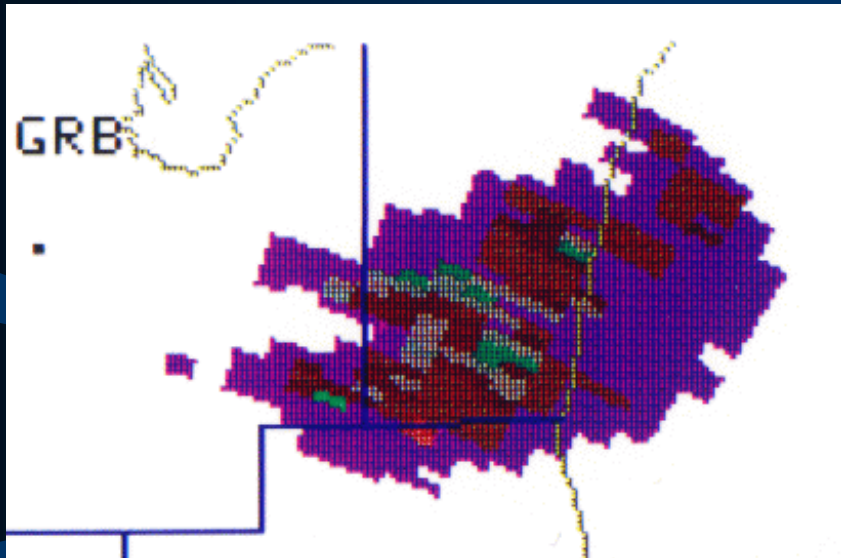


Structurally,
this storm is
not very
impressive.



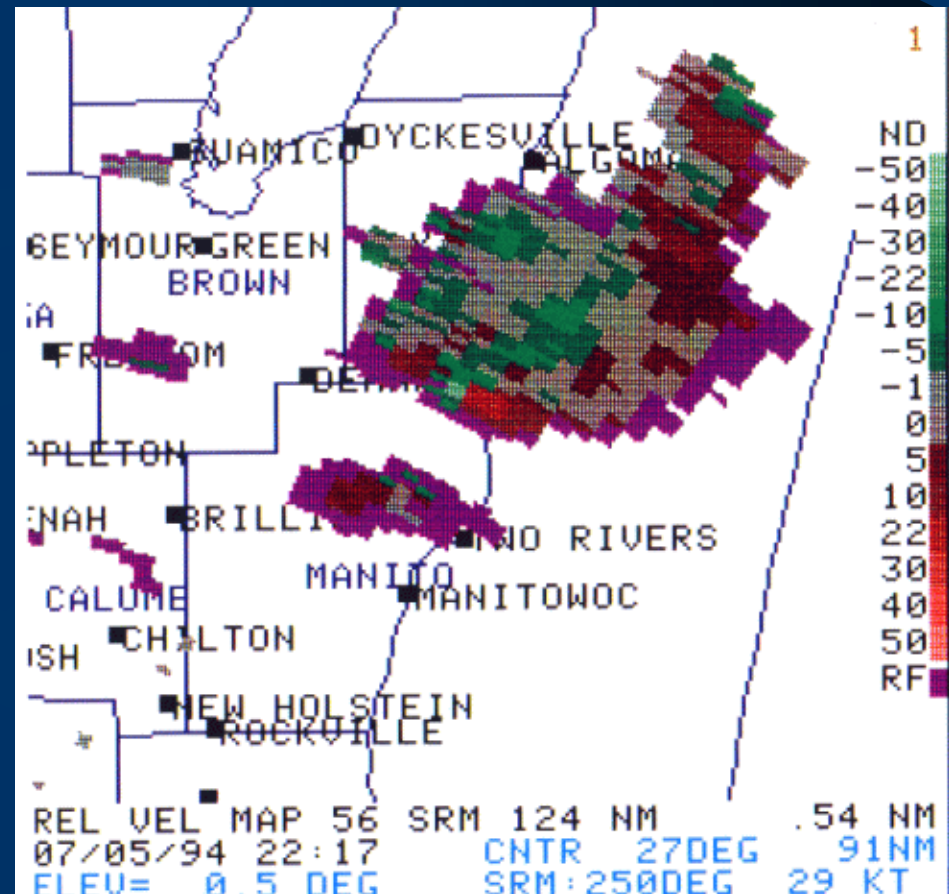
July 5, 1994 at 4:48 PM. Cooperstown F3 tornado on the ground from 4:43 - 4:55 PM! Let's take a look at the velocity data.

Pulse Storm in Manitowoc County



0.5° slice at 4:48 PM

Range folding is obscuring data. Some hint of rotational couplet. F3 on ground for 5 minutes already.

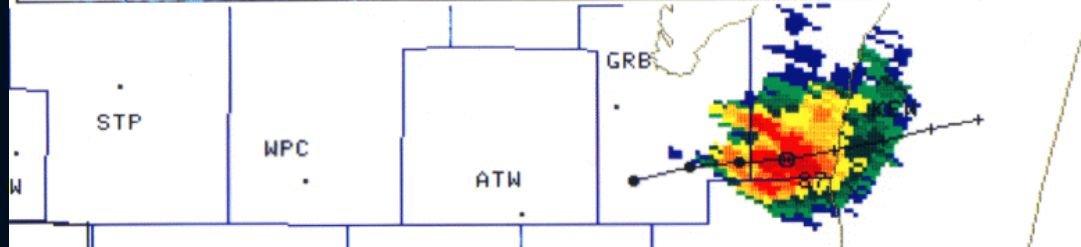


0.5° slice at 5:17 PM

By now, tornado no longer on the ground. Rotation more apparent, however.

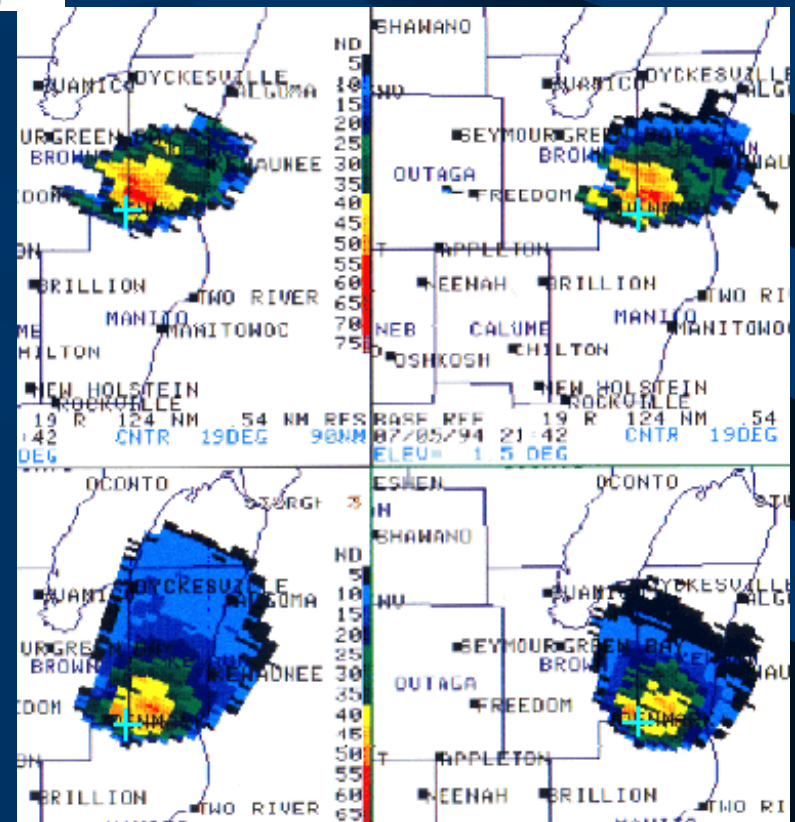
Pulse Storm in Manitowoc County

STM ID	AZ	RAN	TVS	MESO	HAIL	DBZM	HGT	ULOW	STM TOP	FCST	MVMT	MW VOL
09	164	115	NO	NO	POS	61	15.1	33	51.02	261	23	19144
87	24	93	NO	NO	POS	57	11.2	46	47.83	258	24	5145
10	160	159	NO	NO	NEG	59	25.7	0	59.35	261	23	6084
G	149	166	NO	NO	NEG	59	27.9	0	62.21	261	23	5177



Attribute table on Composite Reflectivity not showing anything very unusual with storm ID 87.

4 - Panel display shows the storm is essentially vertically stacked.

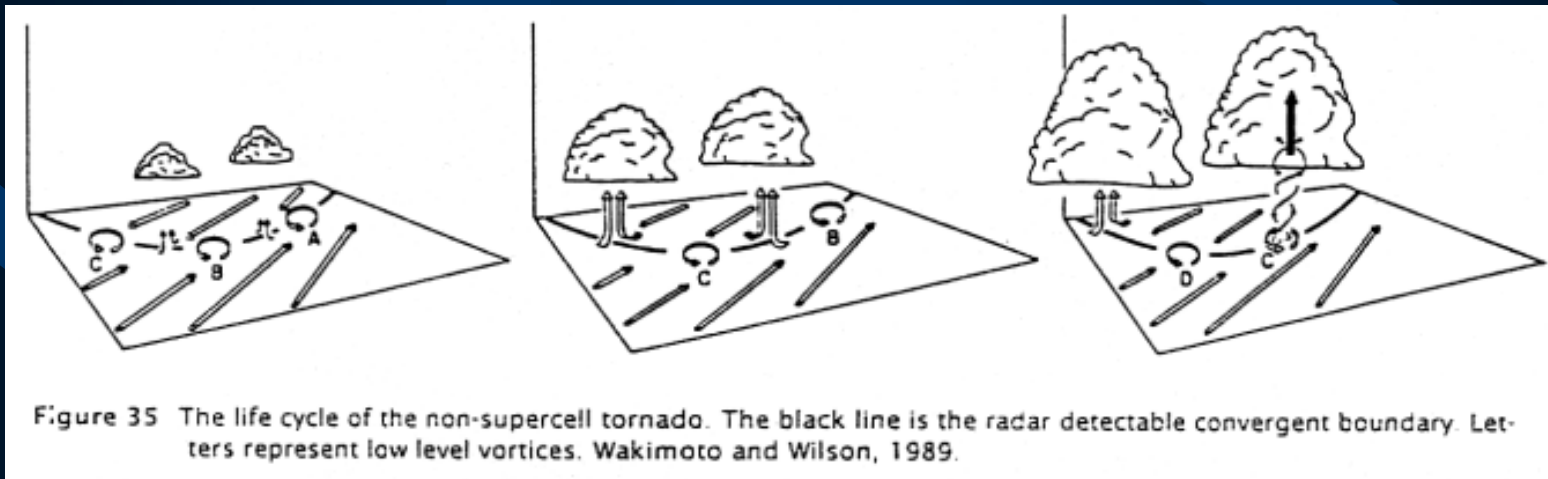


Pulse Storm in Manitowoc County

It was concluded that the Cooperstown Tornado spun up from the ground up. As the isolated pulse storm hit the lake breeze boundary, the available horizontal vorticity was stretched vertically very quickly by the strong updraft of the storm. This helped produce the 12 minute, 3.5 mile long, F3 tornado.

Due to the rapid development, and tornado genesis occurring from the surface to cloud base, this type of tornado is extremely difficult to issue warnings with appreciable lead times.

This tornado caused \$2.1 million in damage and injured 2 people.

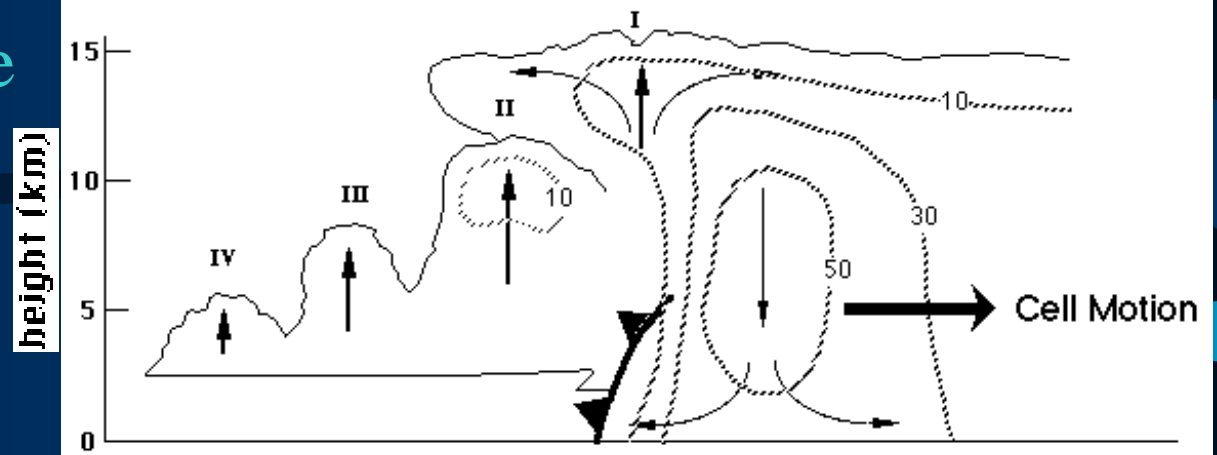


The Multicell Cluster/Line

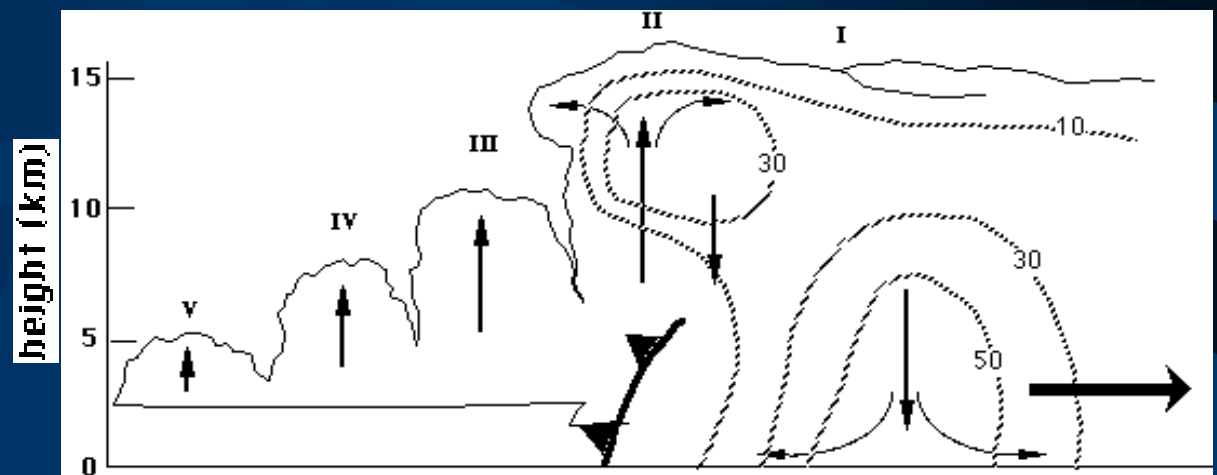
- Multicell Clusters and Lines will often evolve from merging Pulse storms. Or, in situations where an environmental cap is “broken”, Multicell Clusters develop almost immediately.
- Quite often the Multicell Cluster will evolve into a Multicell Line or even a Supercell(s).
- These systems are generally long-lived and if identified as severe, the warning decision process becomes somewhat straight forward. This is especially true for large Multicell Lines producing widespread damaging winds. May 31, 1998 comes to mind...

Tornado and Severe storm Warning Criteria Guidelines are the same as for Pulse storms. There are some additional factors to consider as well...

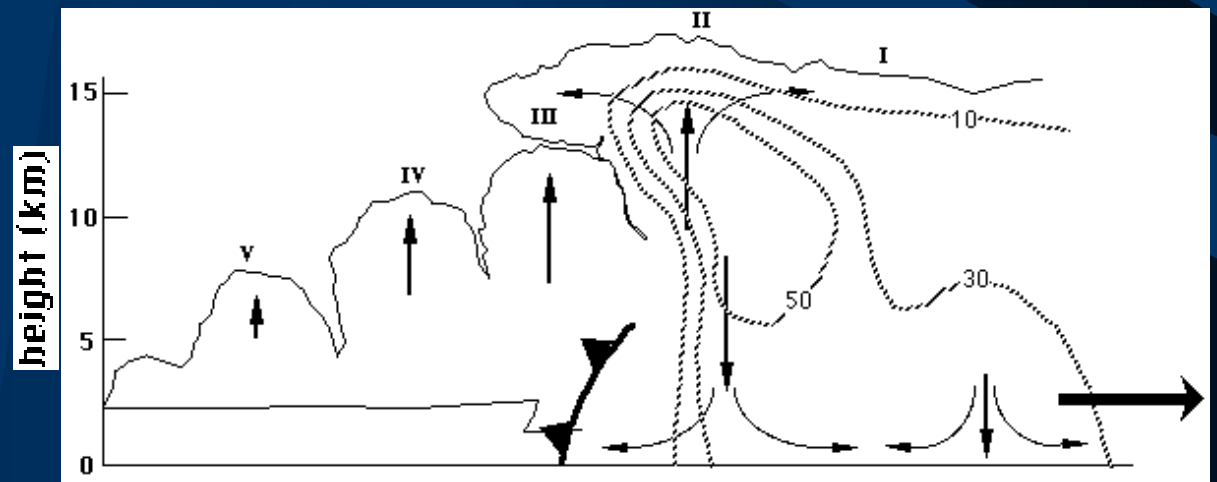
Early stage



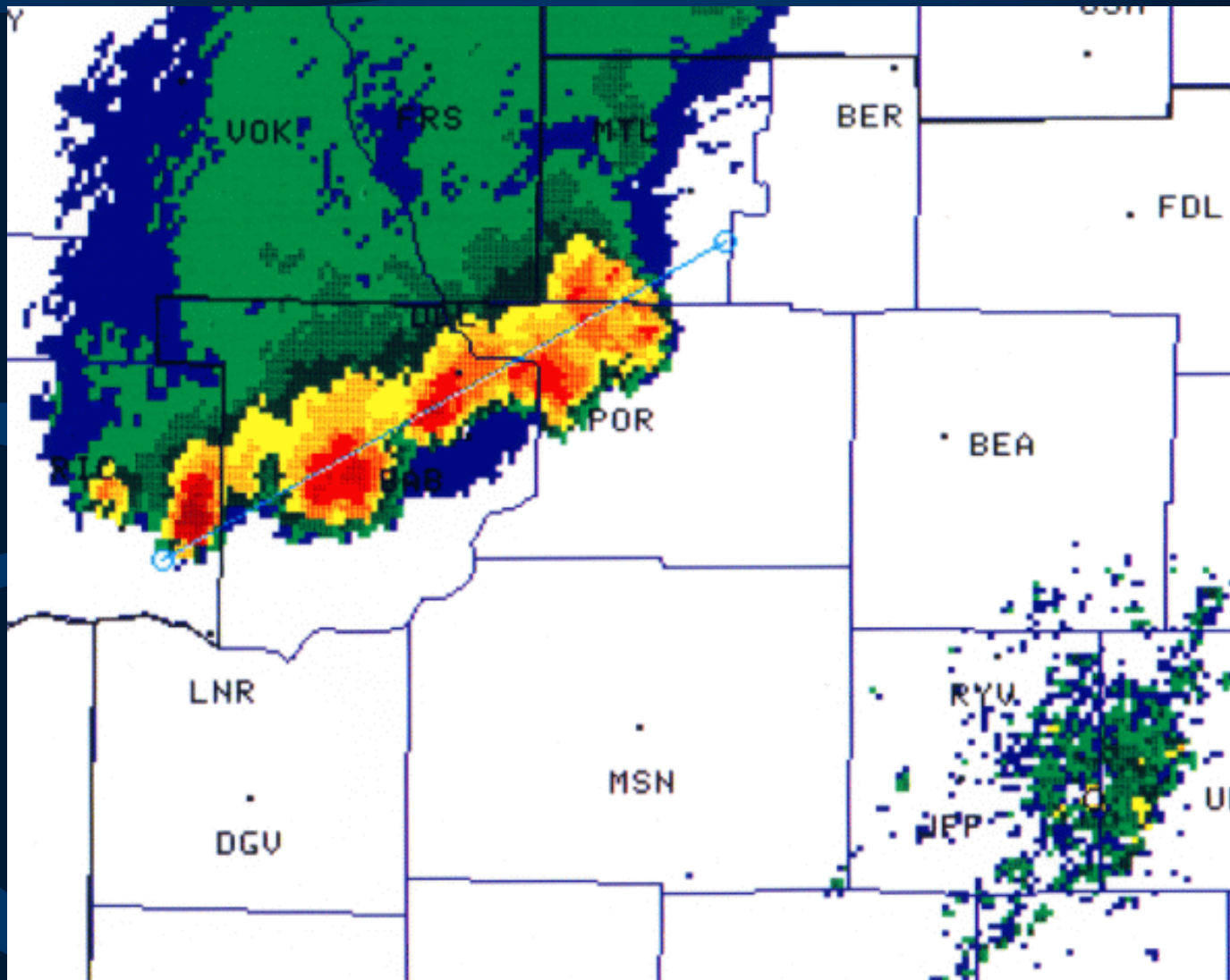
Next evolution



Later stage

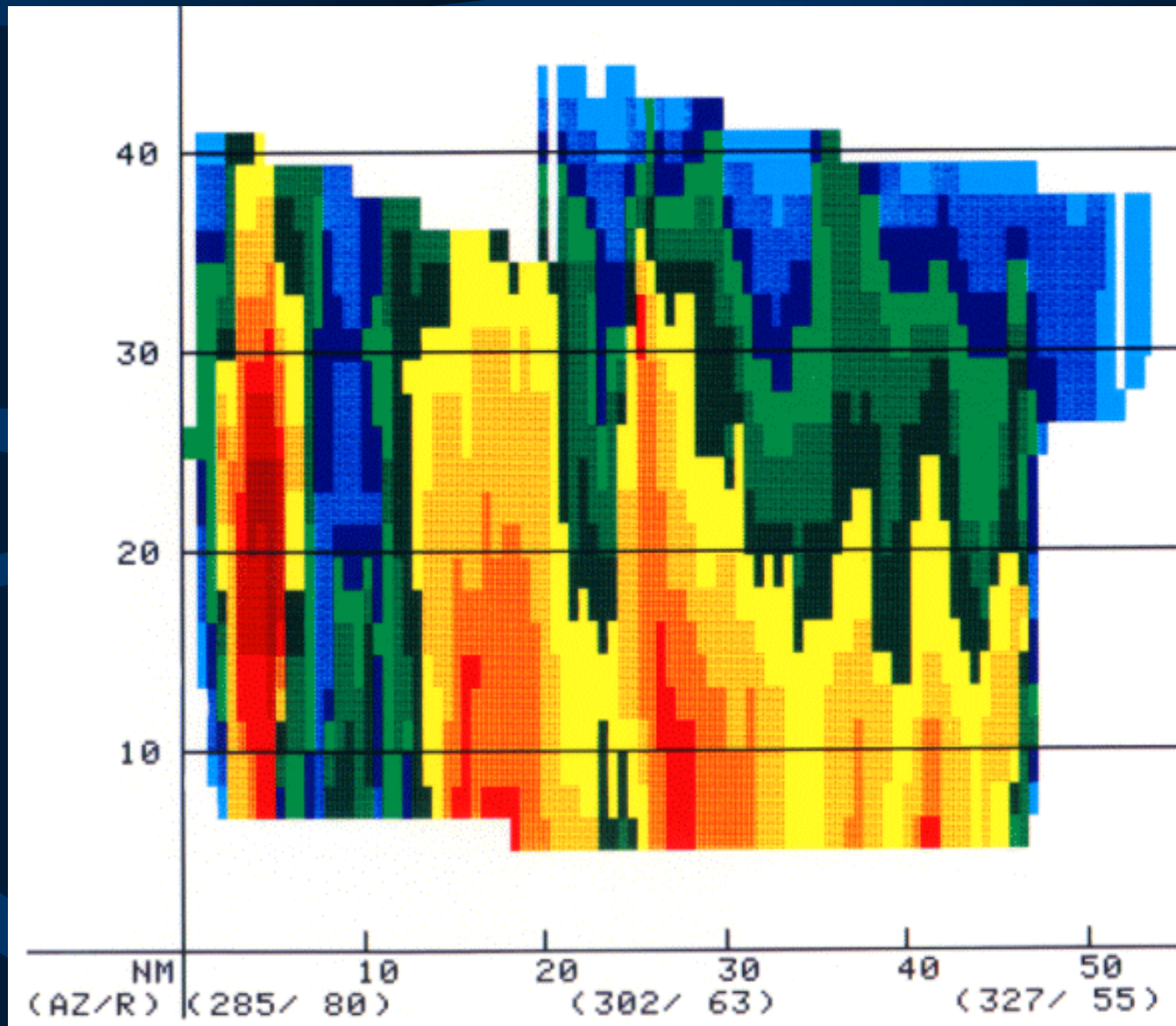


Multicell Line



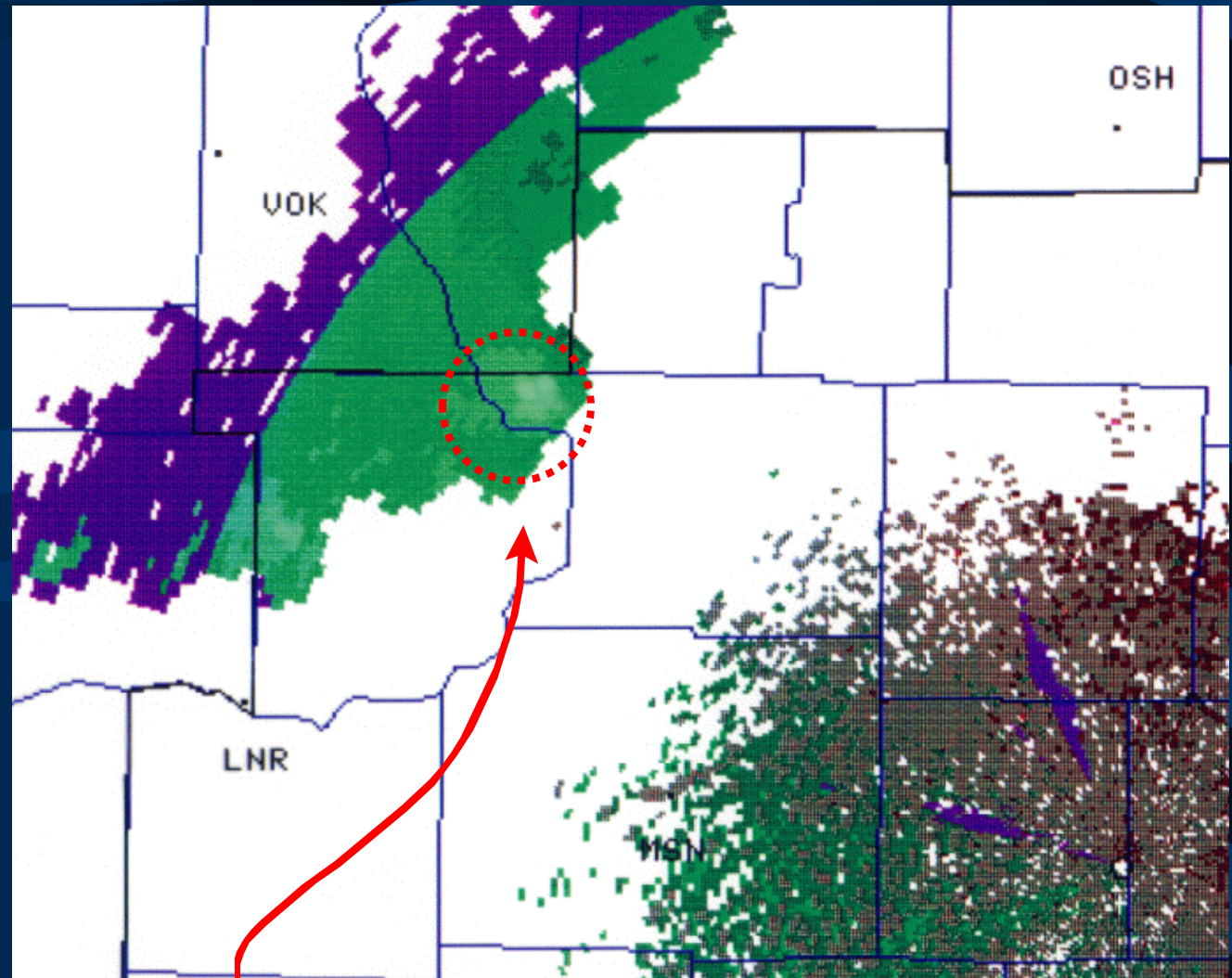
July 11, 1994 5:55 PM

Multicell Line



Multicell Line

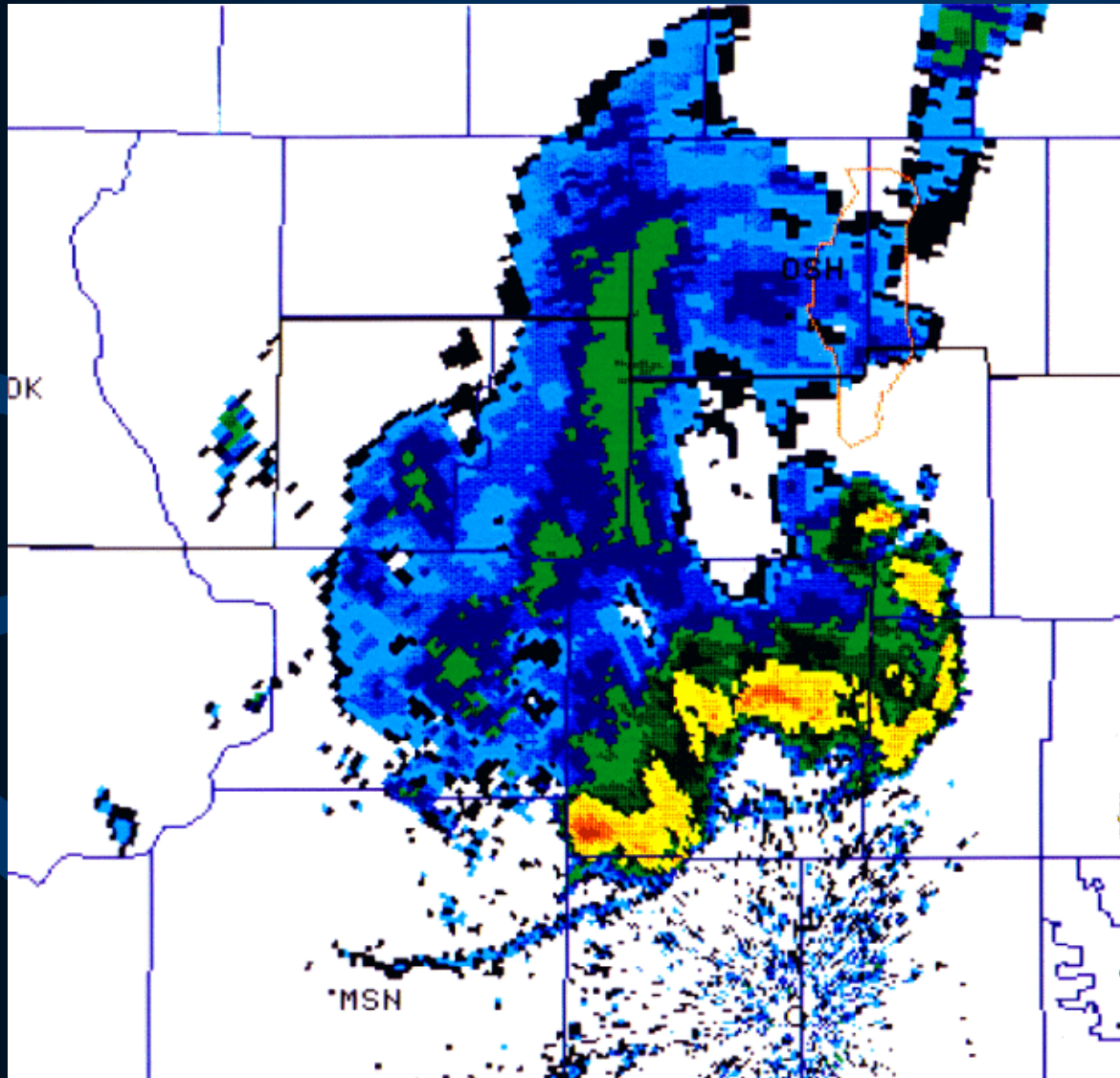
Often, the older, collapsing storms will be the severe weather producers



Max 66kt Inbound

At this time, the Severe reports (wind) came from Sauk and Northern Columbia county (the Dells)

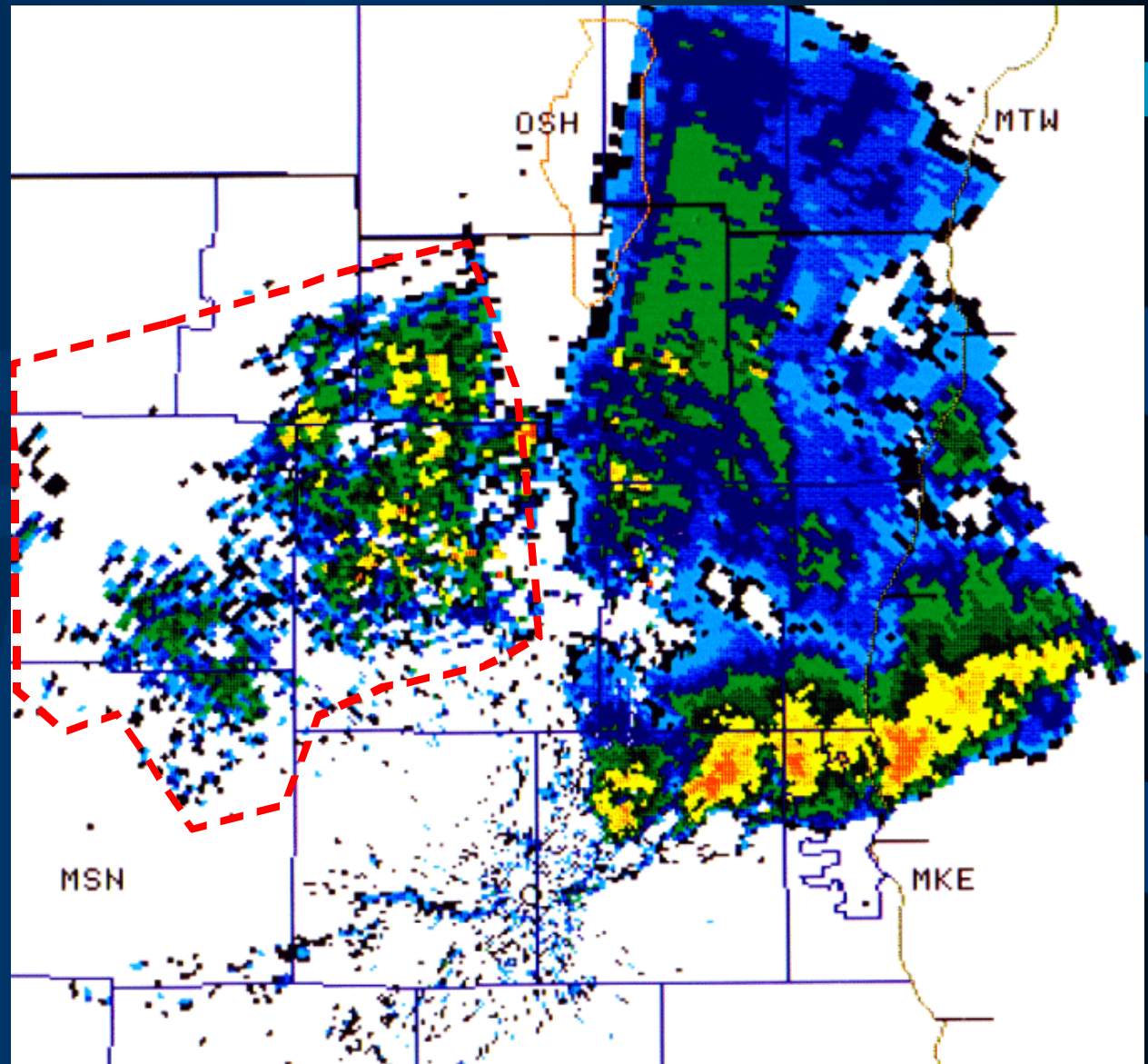
Multicell Line



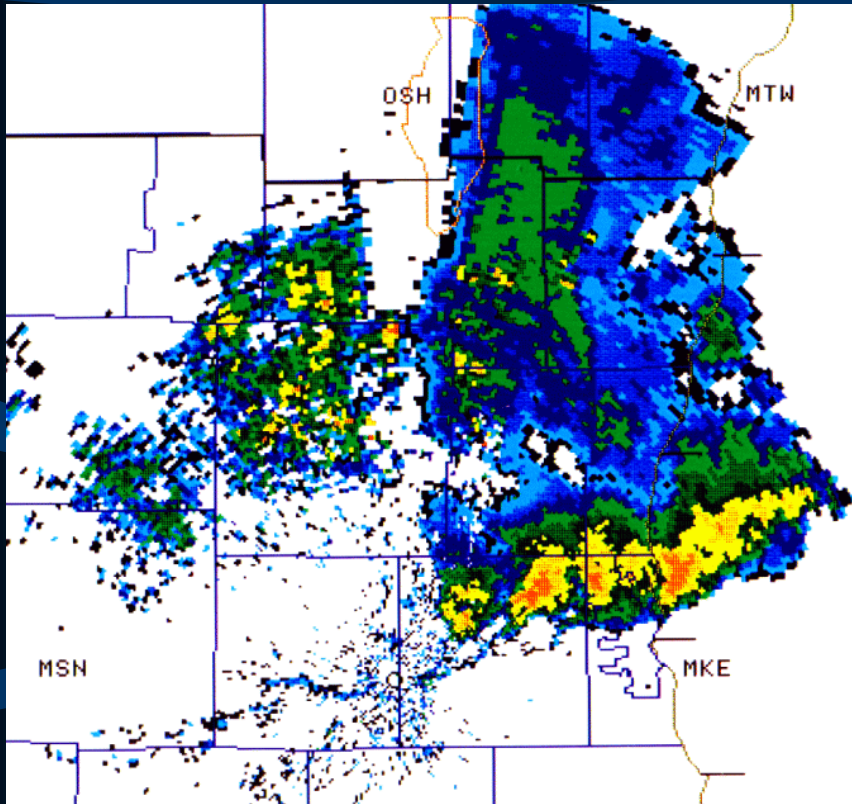
Intersecting outflow
boundaries

Multicell Line - Wake Phenomenon

What is this?

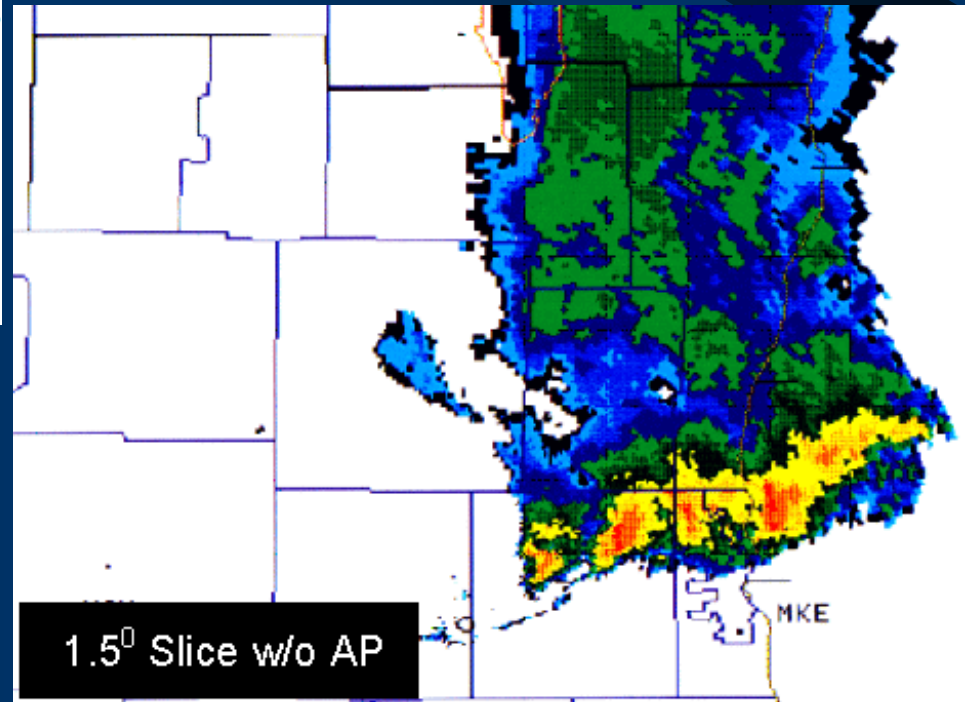


Multicell Line - AP mitigation

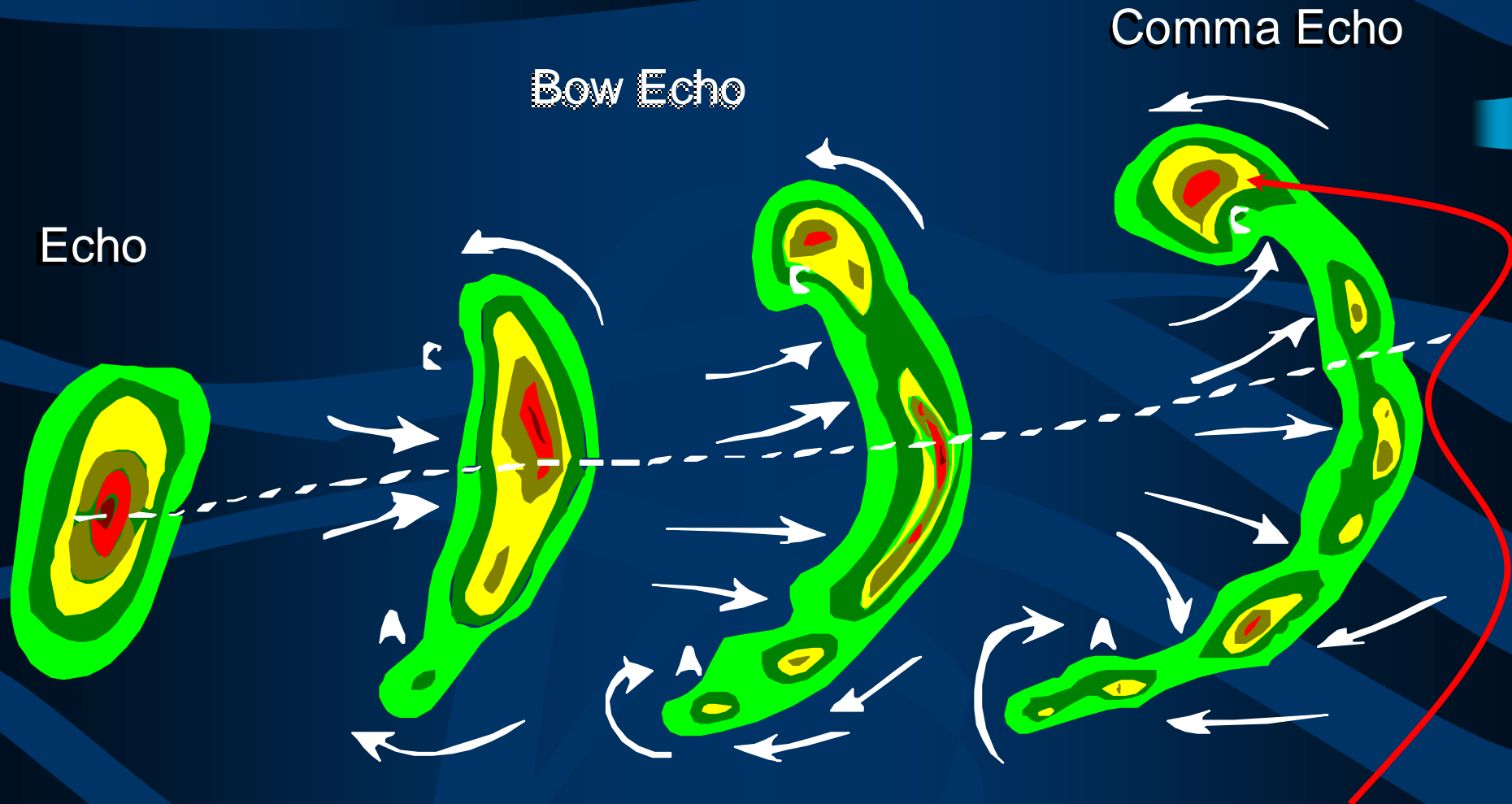


Mitigate “wake AP” by raising elevation about 1 degree.

Anomalous Propagation in the wake of storms. Cold outflow produces superrefractive conditions.



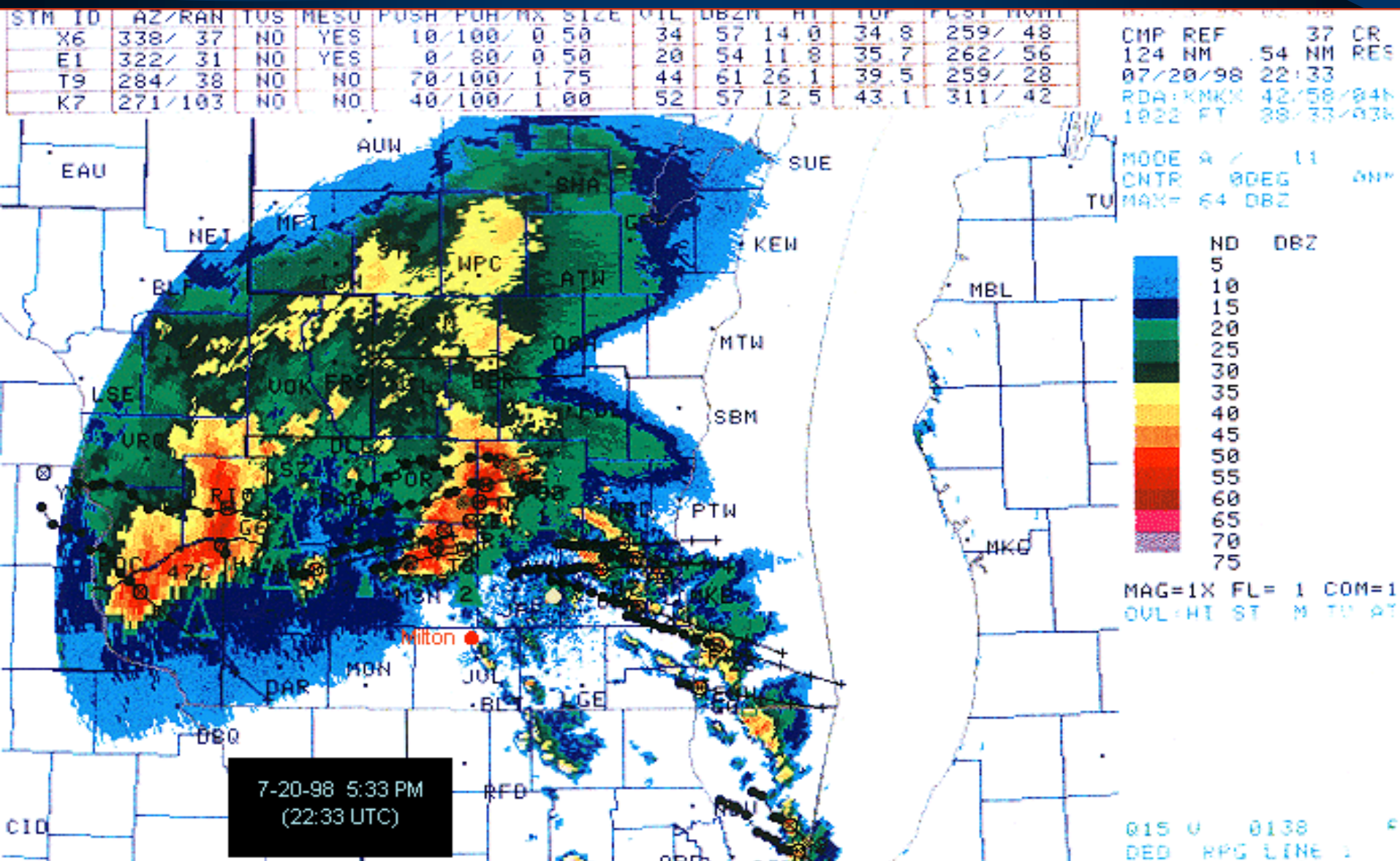
Downburst Evolution



Watch the head of the comma for quick tornado development.

The tornadoes in these cases are generally weak and short-lived.

Multicell Line

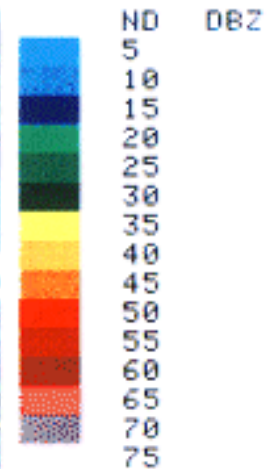


Multicell Line

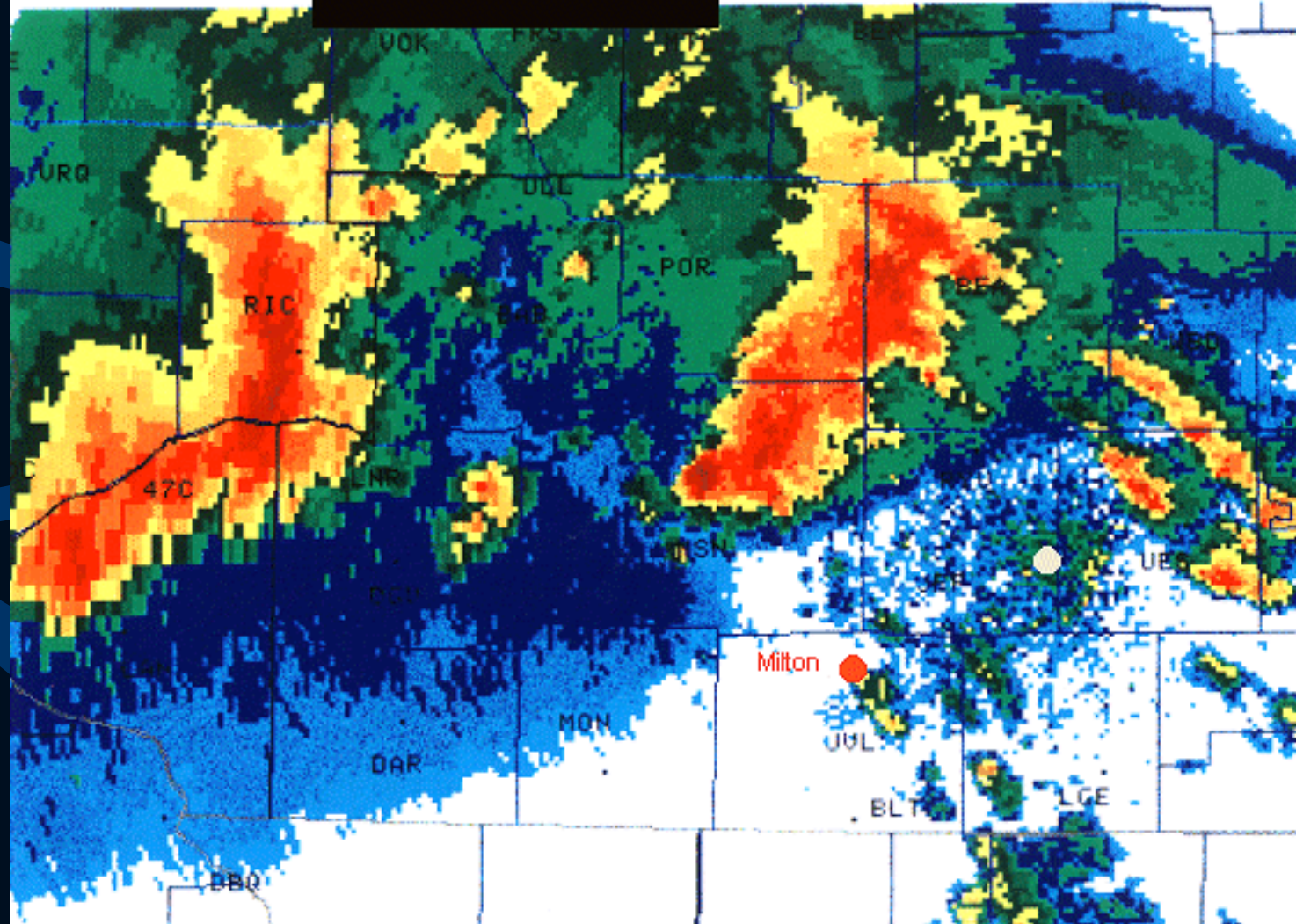
7-20-98 5:33 PM
(22:33 UTC)

CMP REF 37 CR
124 NM 54 NM RE
07/20/98 22:33
RDA:KMKN 42/58/04
1022 FT 88/33/03

MODE A / 11
CNTR 2670EG 42N
MAX= 64 DBZ

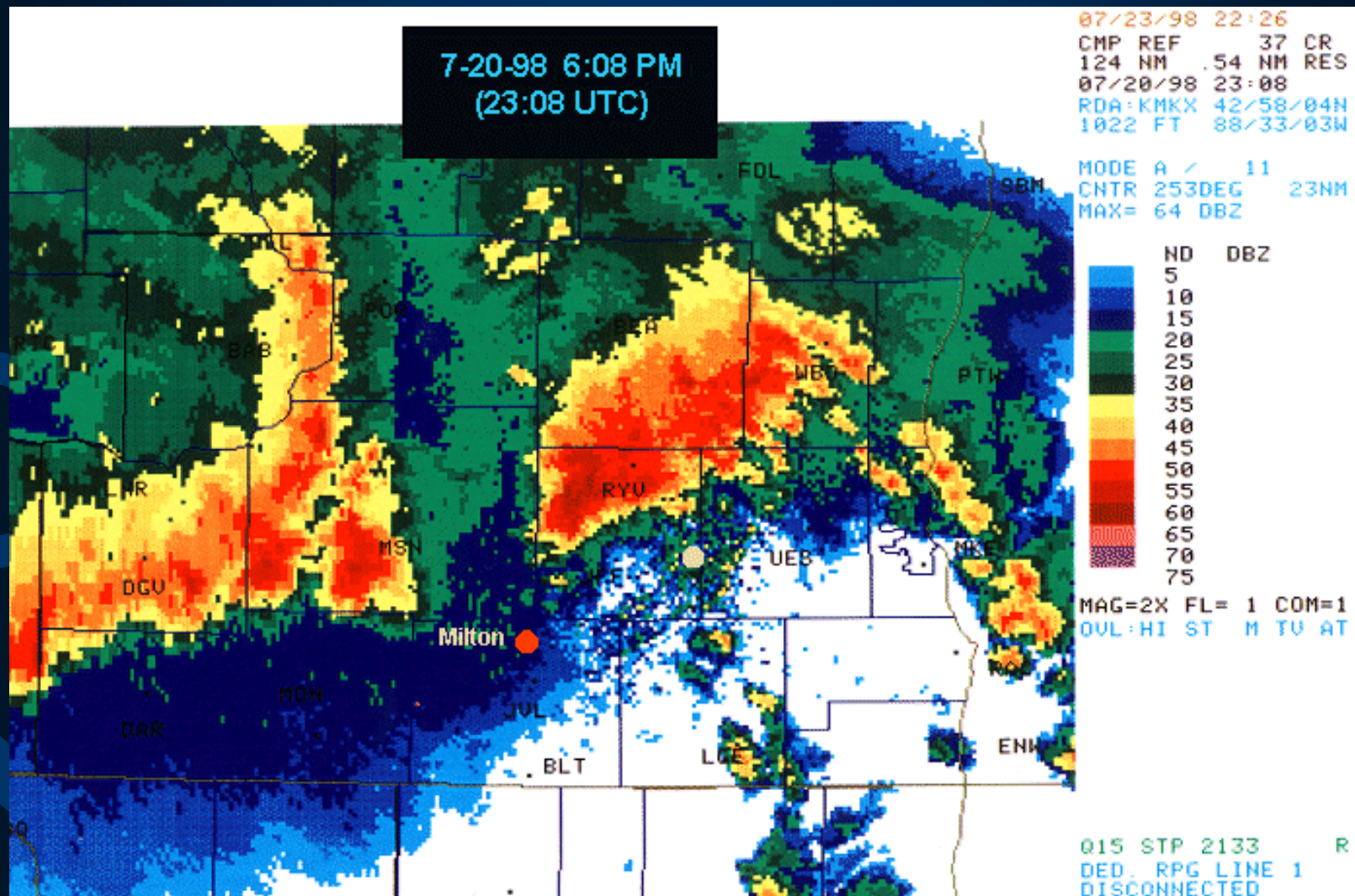


MAG=2X FL= 1 COM=
OUL-HI ST M TU A



015 U 0138
DED. RPG LINE 1
DISCONNECTED

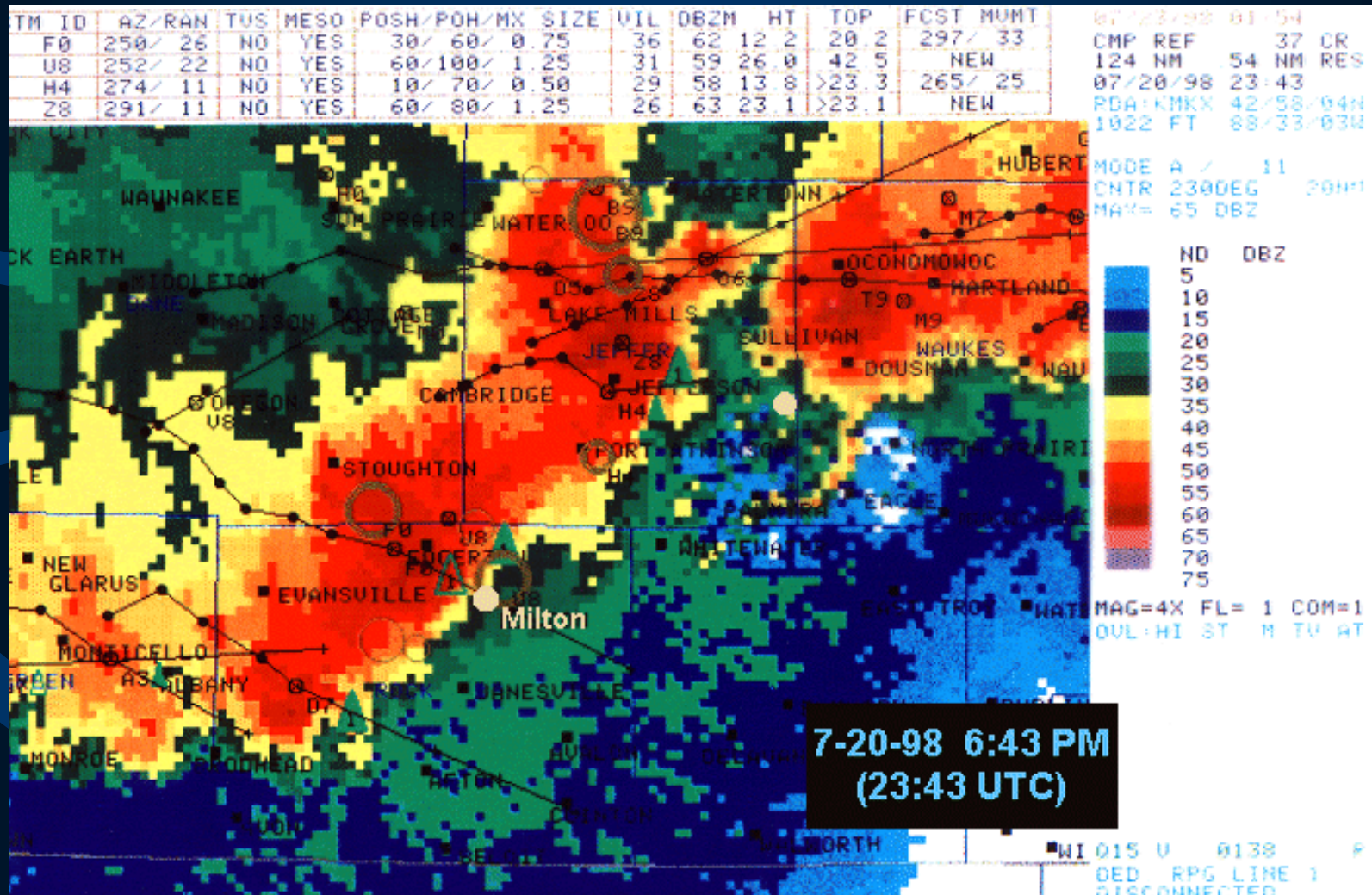
Multicell Line



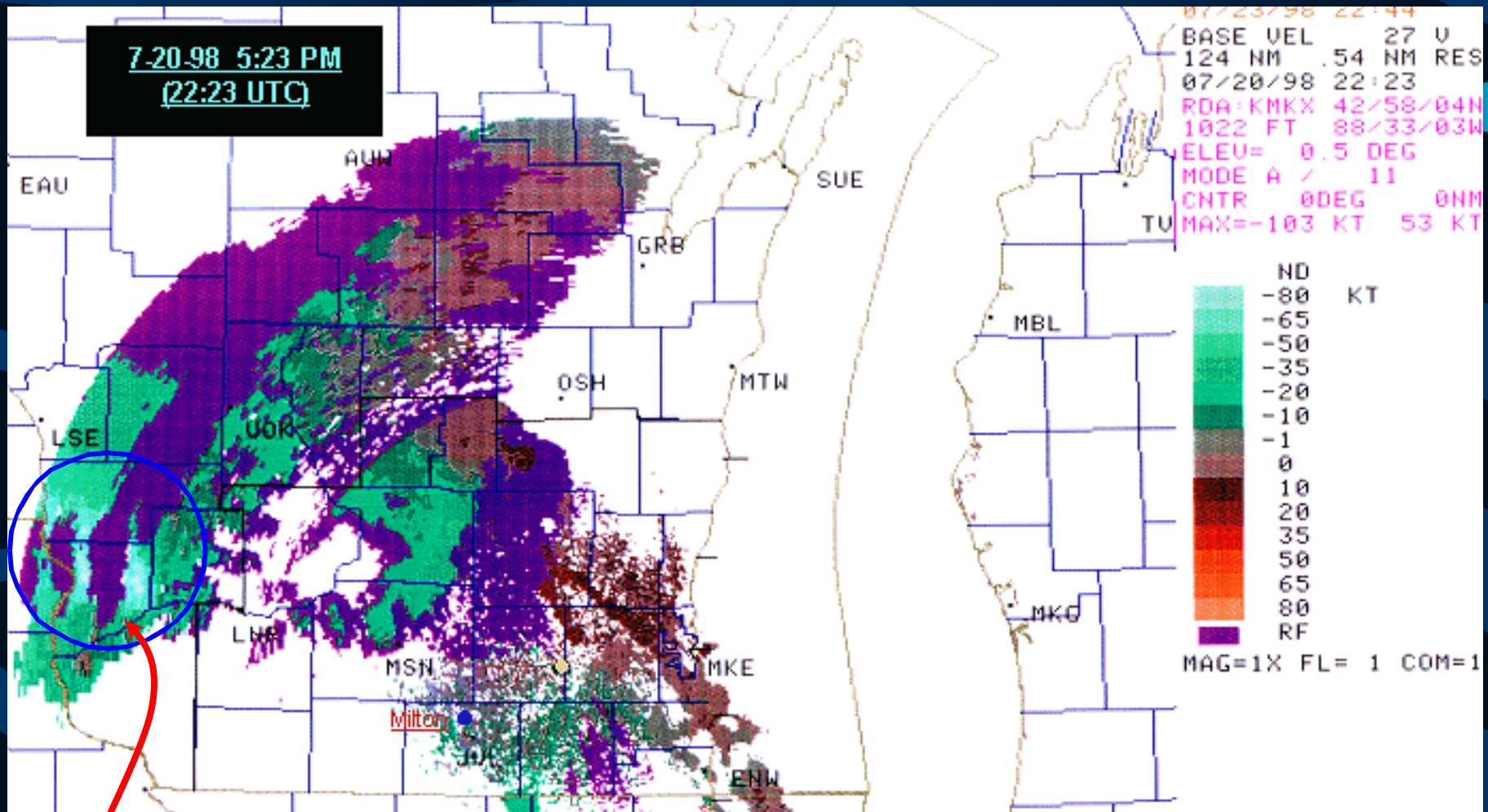
Note: Leading cell now merging with bowing line

Multicell Line

Merger caused line to intensify rapidly. It produced 70 mph winds in Milton...100 mph winds in Walworth county.

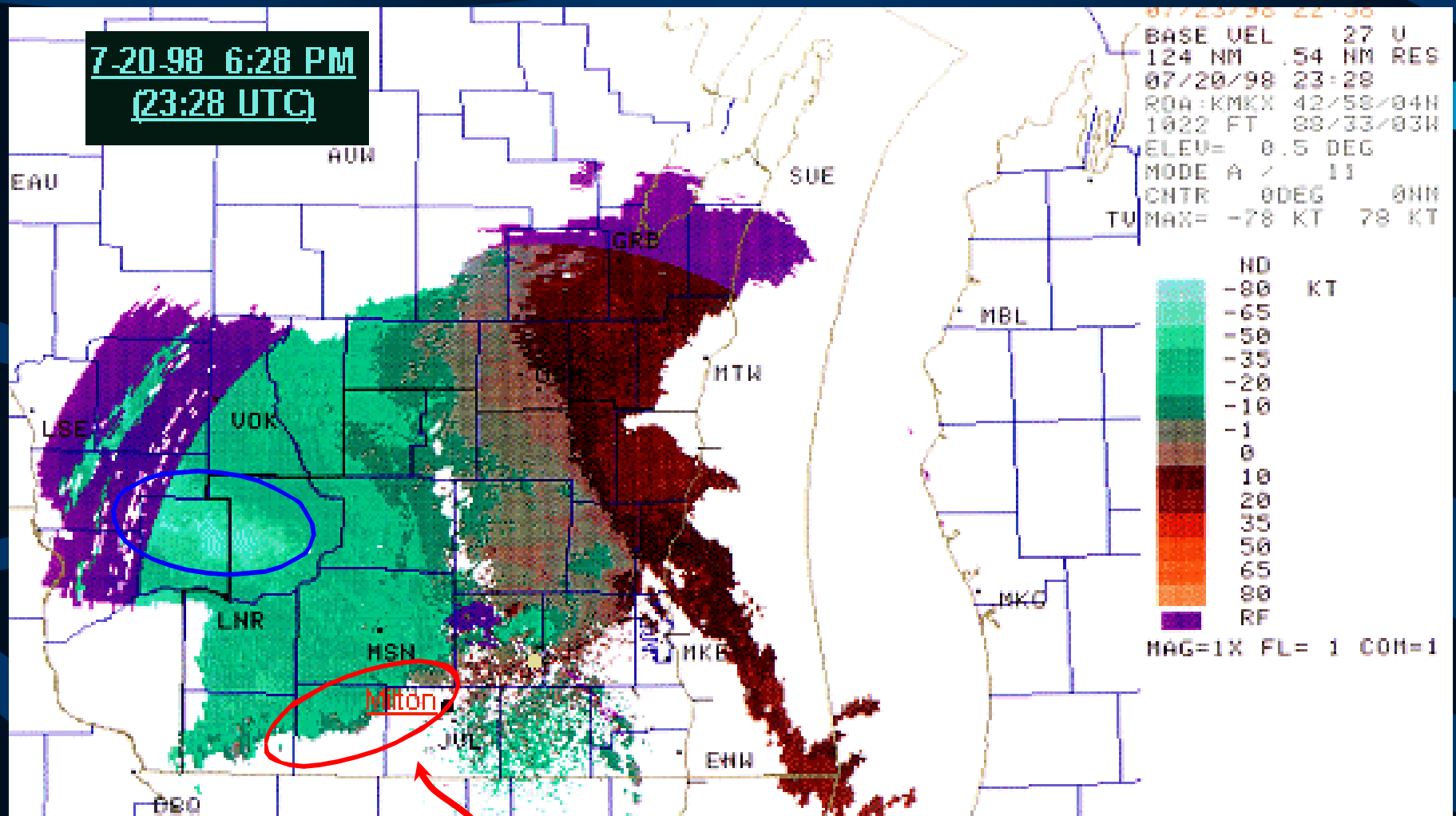


Multicell Line



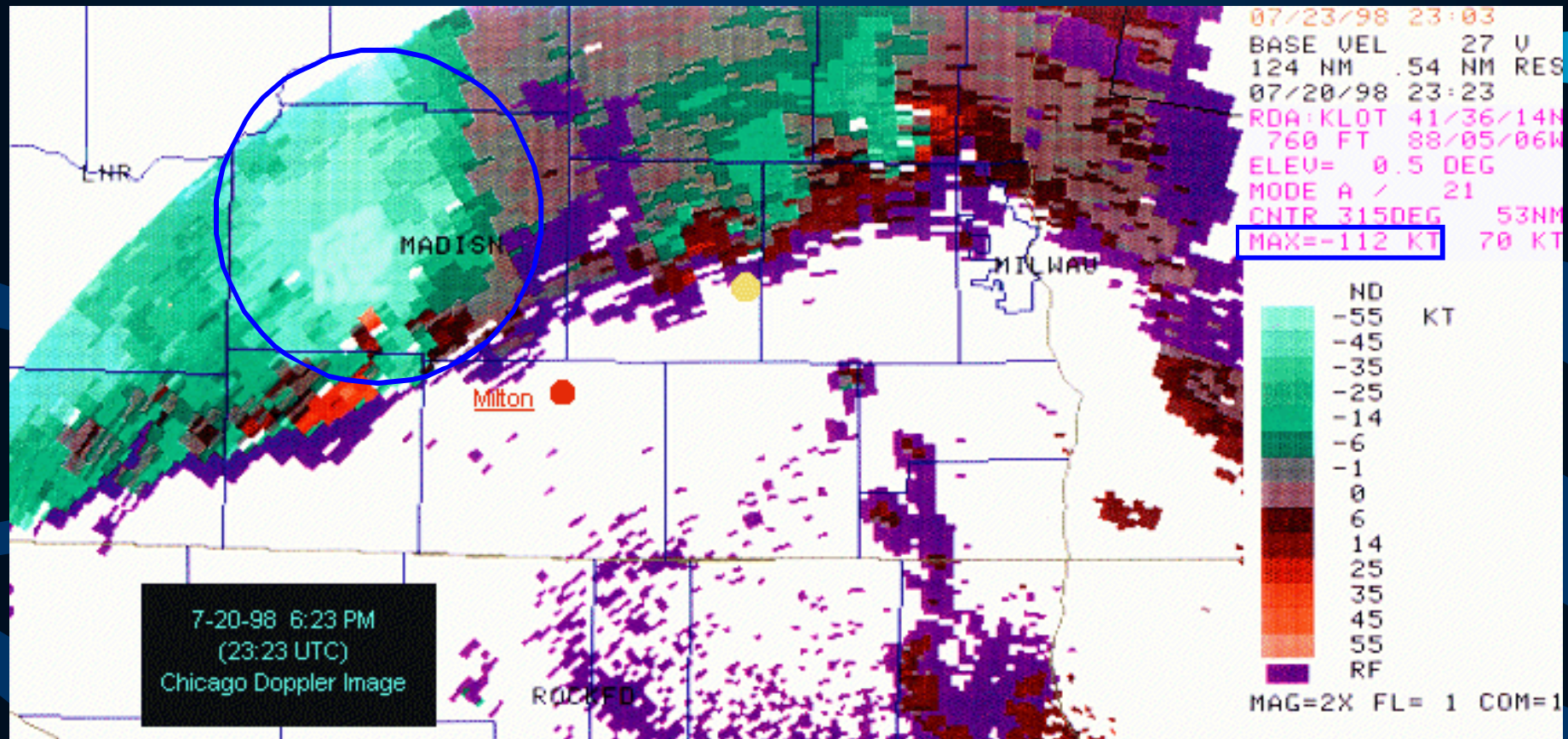
Barn destroyed in Crawford county with 90 mph winds reported.

Multicell Line



Zero Isodop (winds perpendicular to radar beam) are causing displayed wind speeds to diminish to near zero along leading edge.

Multicell Line

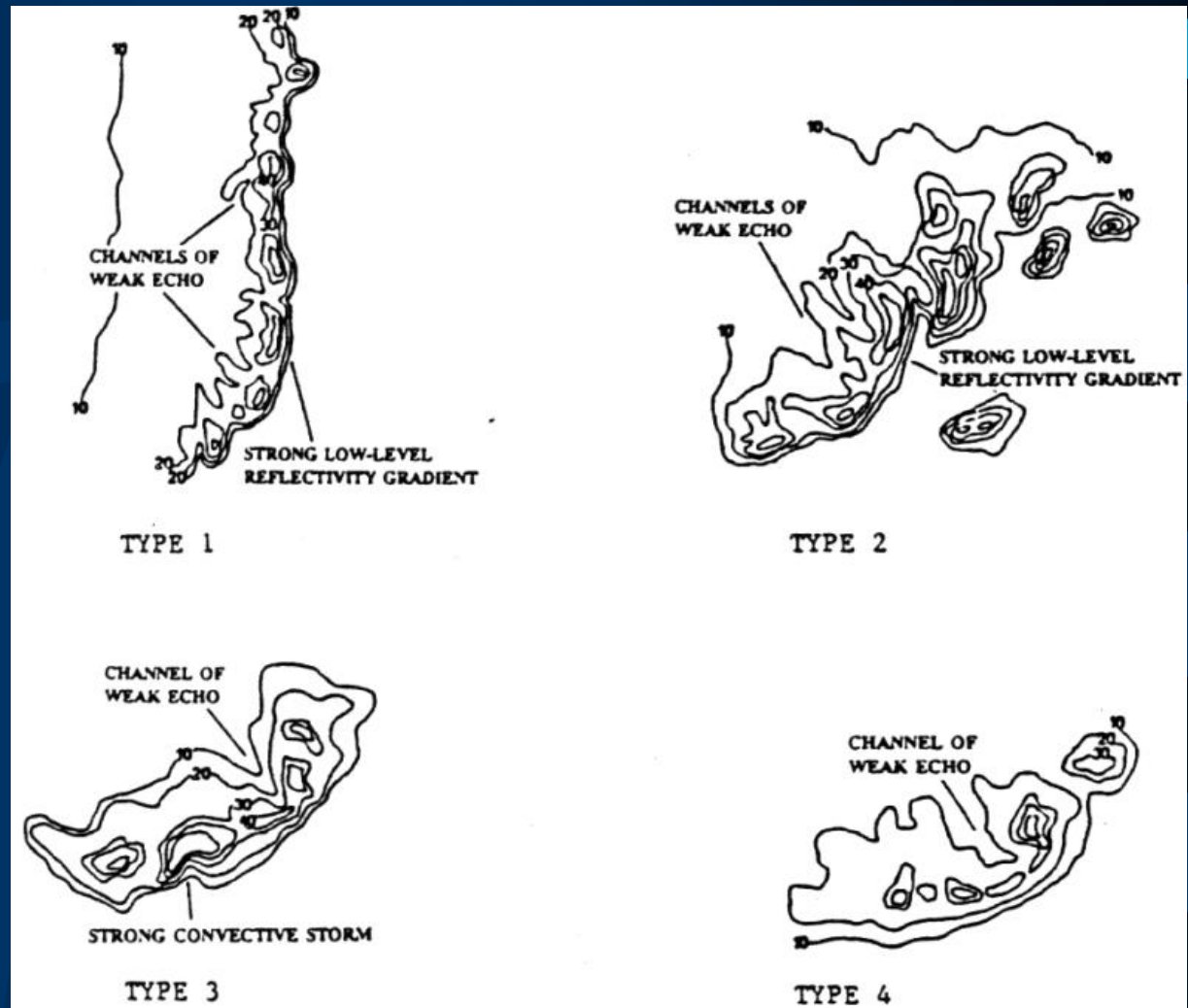


We mitigate some Zero Isodop problems by calling surrounding 88Ds.
In this case, this is the bow as seen by the Chicago 88D.

Multicell Lines - Rear Inflow Notches

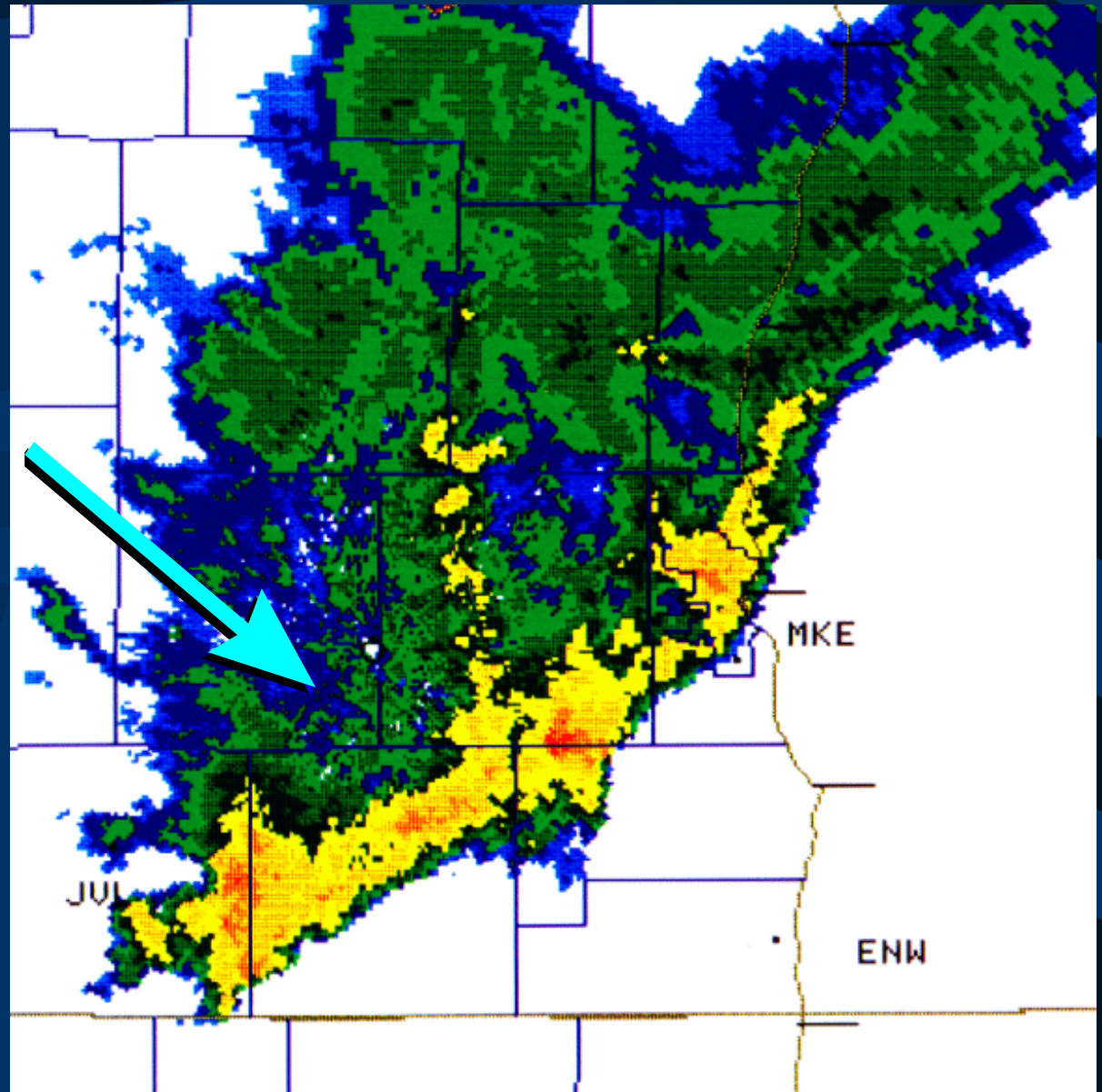
Although this figure shows 4 identified types of bow echo configurations, the consistent feature among the 4 is the channel of weak echo in the rear of the bow structure.

This is often referred to as the **Rear Inflow Notch**.



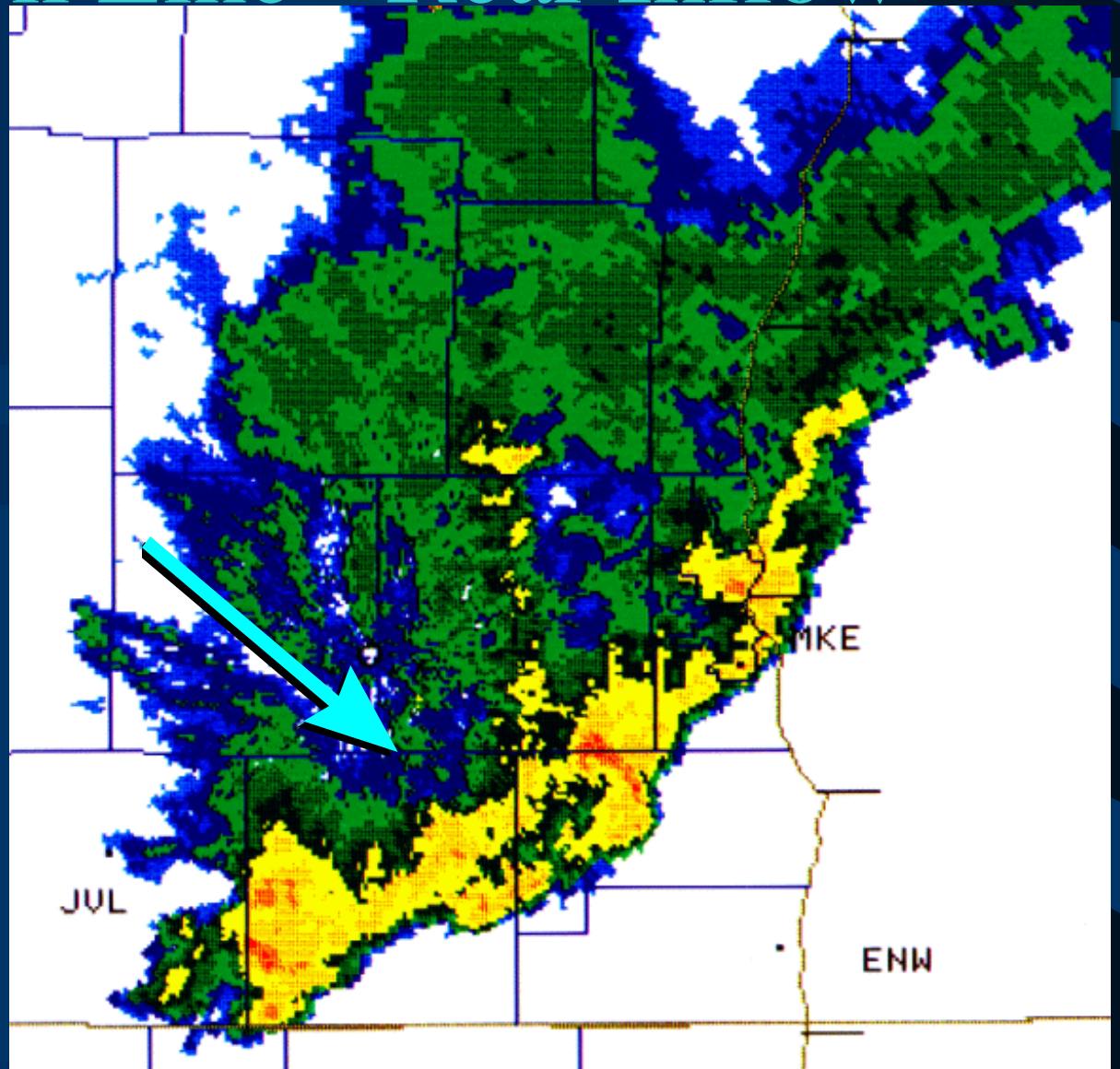
Multicell Line - Rear Inflow Notch

June 8, 1995 at
00:48Z



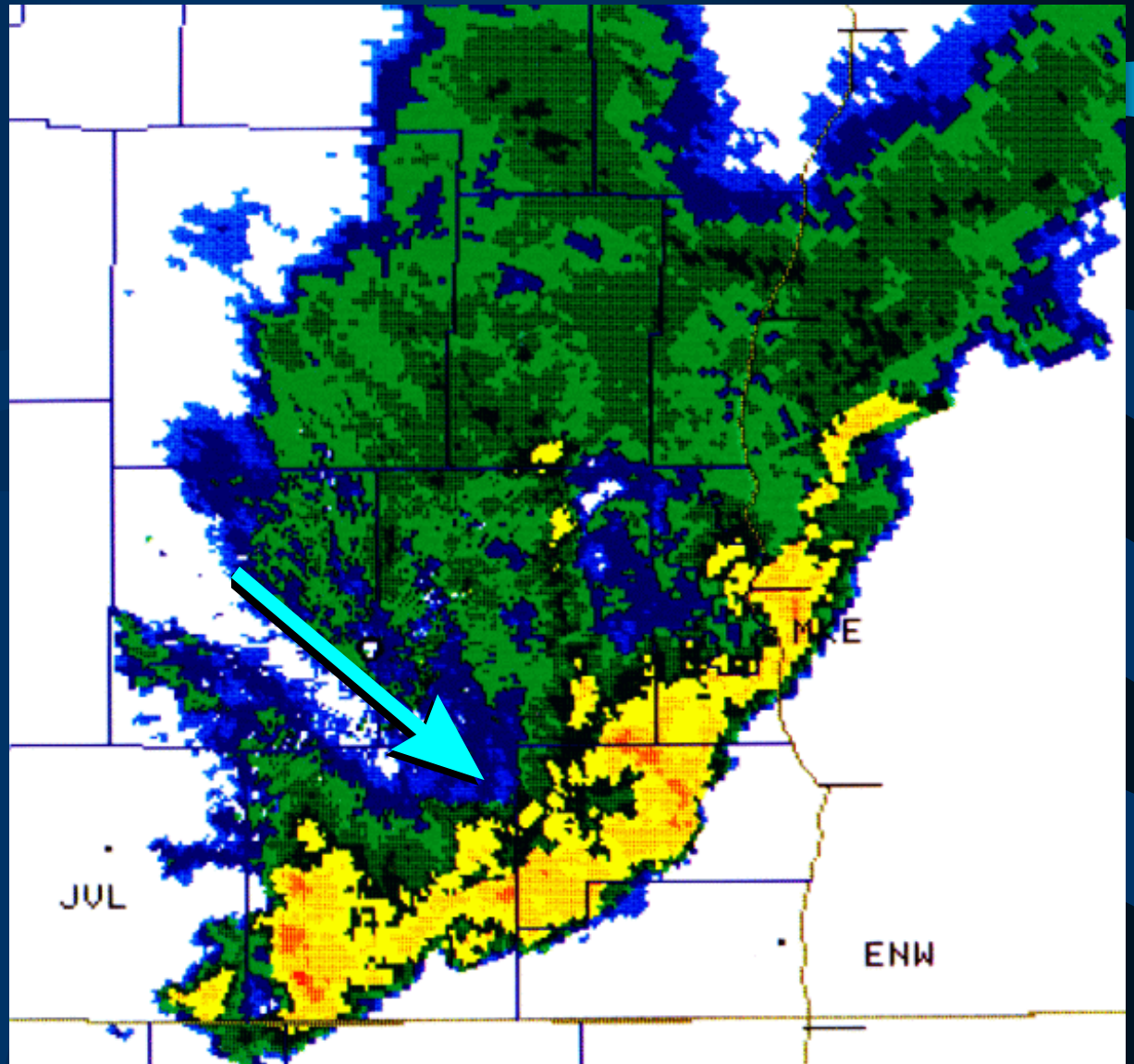
Multicell Line - Rear Inflow

June 8, 1995 at
00:53Z



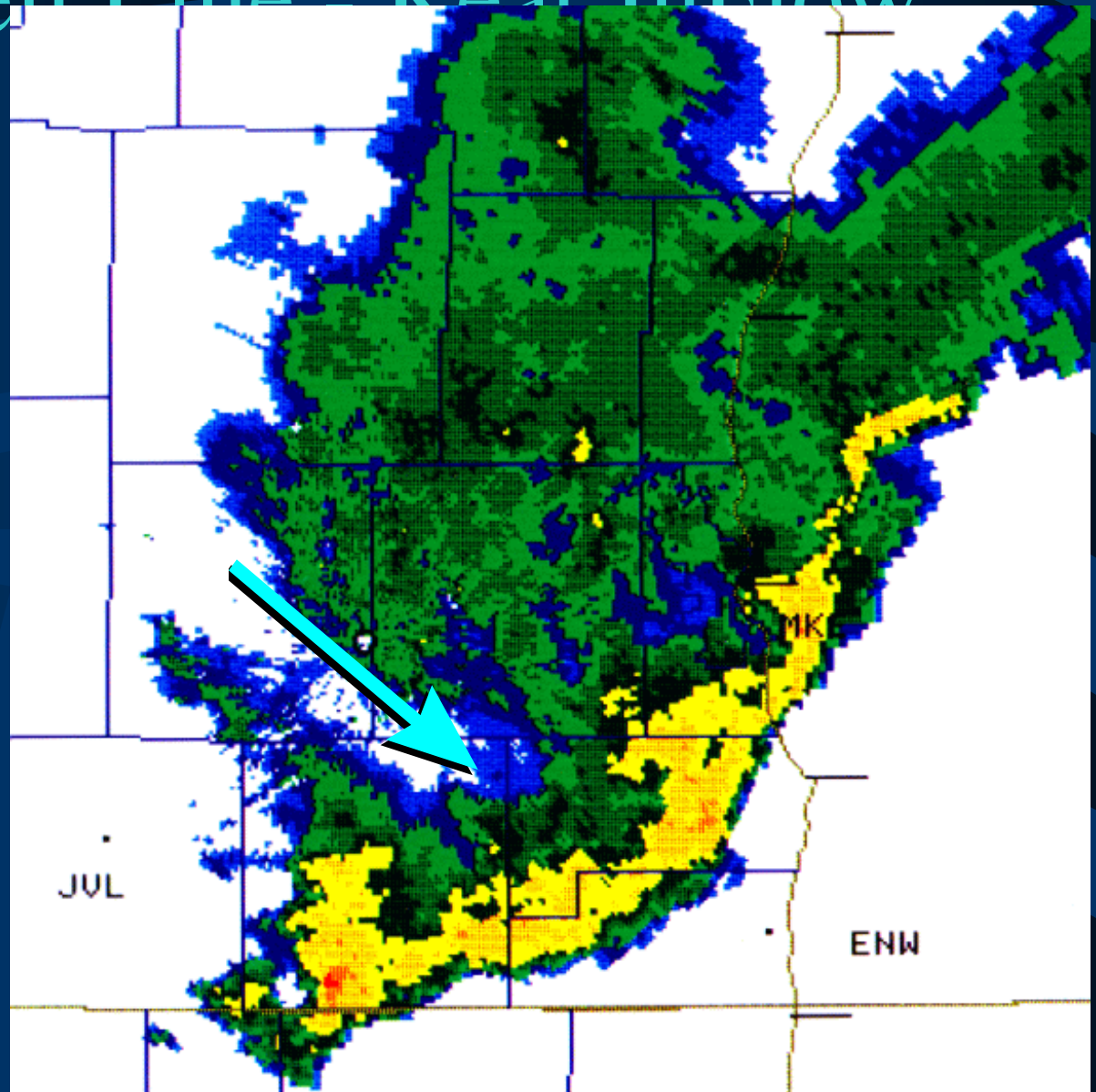
Multicell Line - Rear Inflow

June 8, 1995 at
00:58Z



Multicell Line - Rear Inflow

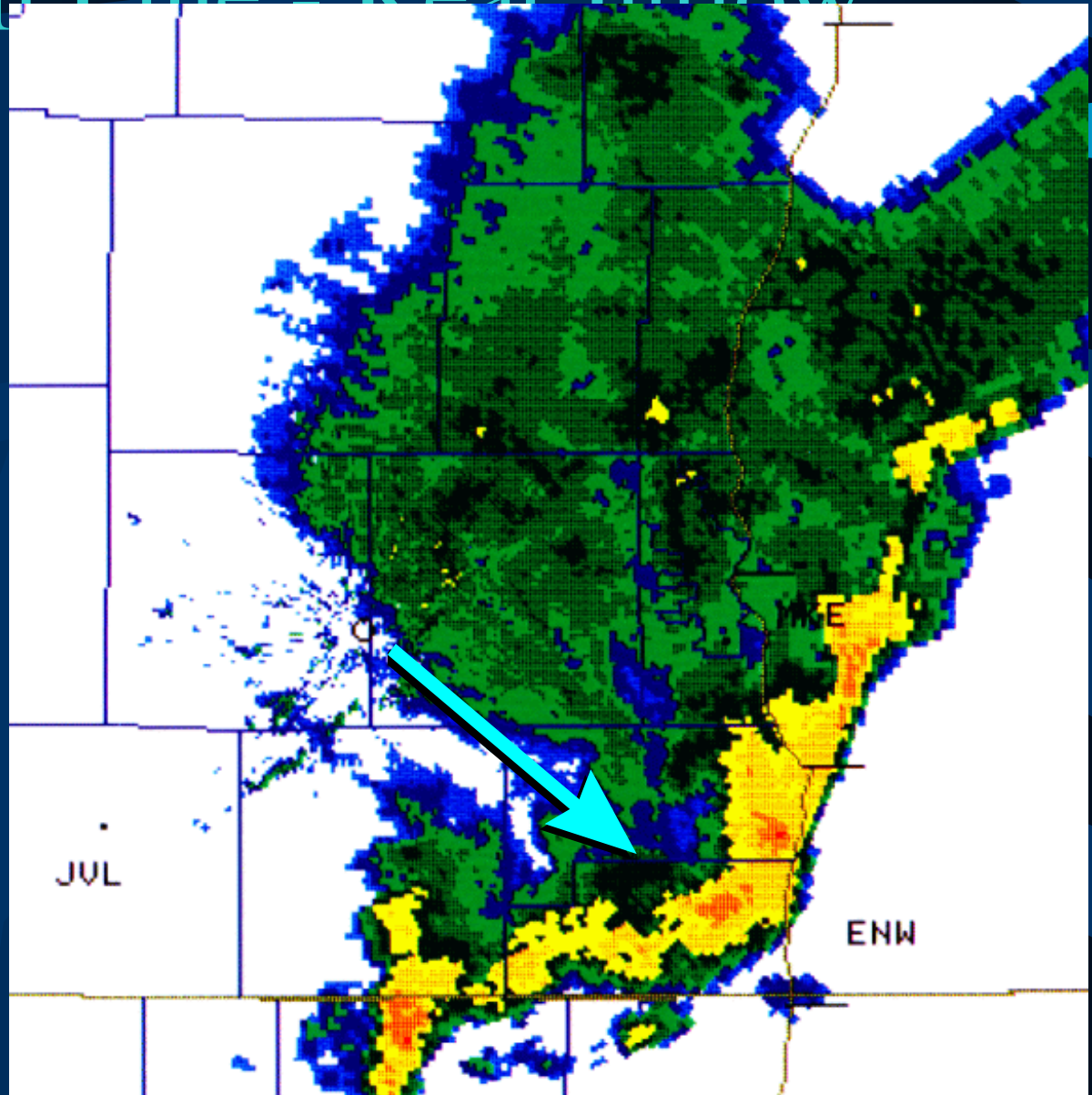
June 8, 1995 at
01:03Z



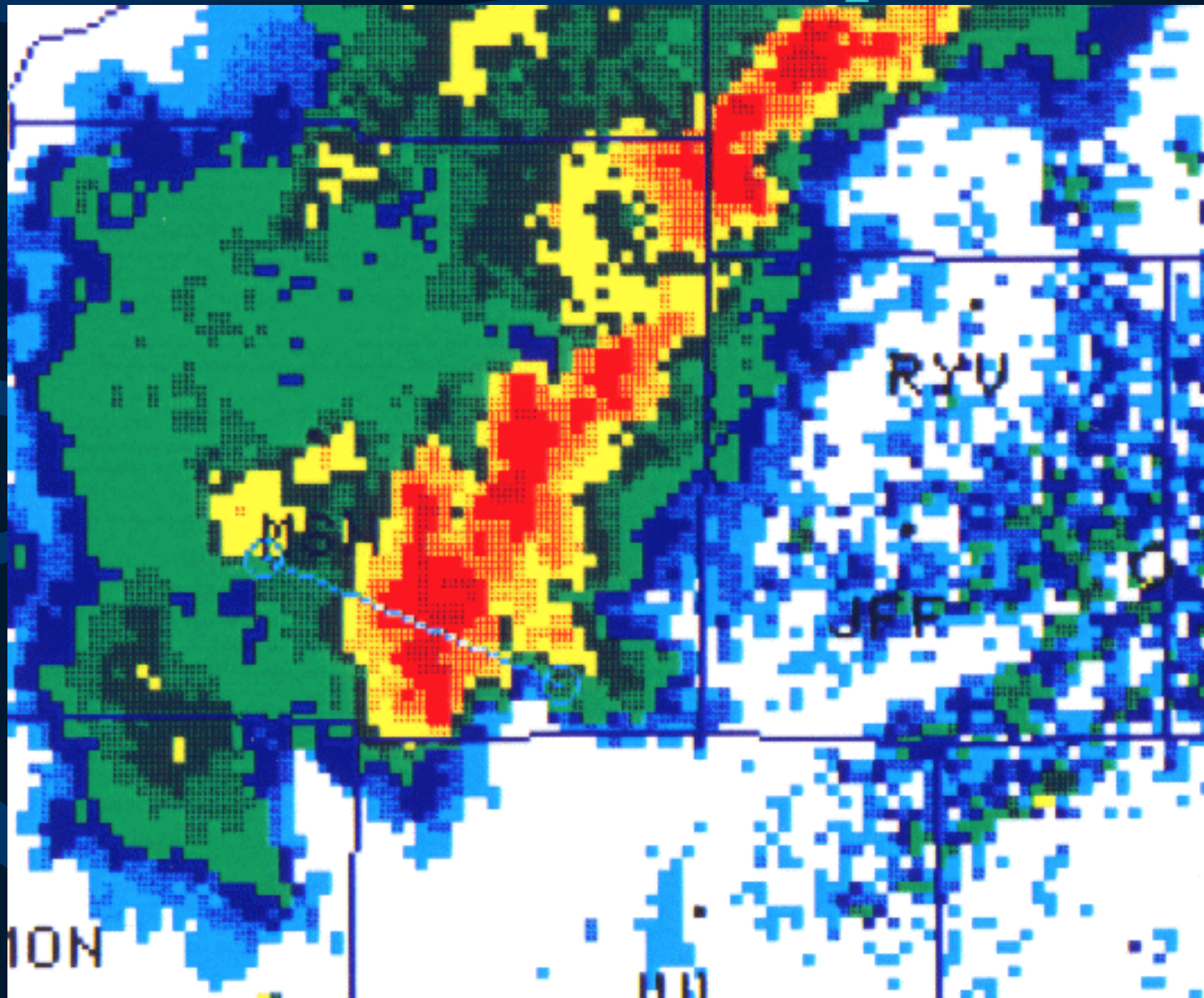
Multicell Line - Rear Inflow

June 8, 1995 at
01:13Z

Wind damage event
across Racine and
Kenosha counties.
Winds were 70+ kts.



Multicell Example



Multicell Cross-Section

Remember the Lemon Technique?

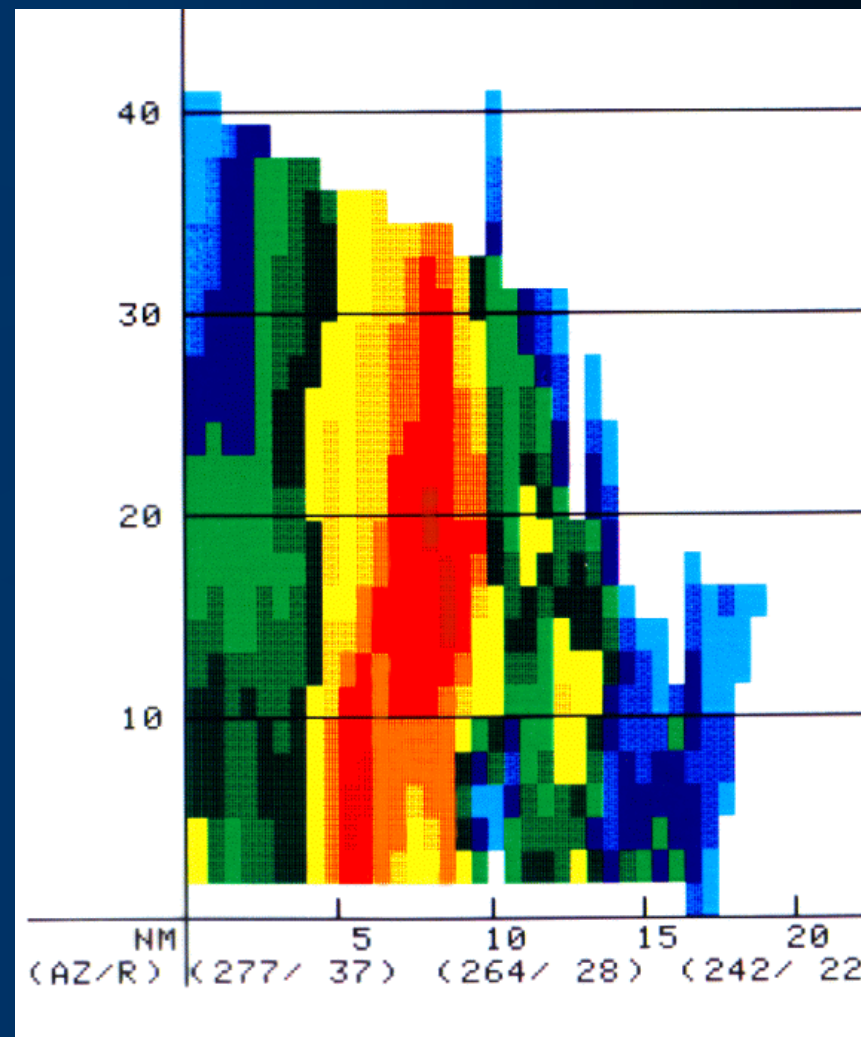
Issue warning if:

- 50 dbz return at 27kft AGL or higher

Or if all of the following are satisfied

- Mid level (16-39kft AGL) return >45 dbz
- Mid level overhang > 3.2 nmi beyond the strong low level reflectivity gradient
- Highest echo top located over the strong low level reflectivity gradient
- * Overhang about 3-4 nmi beyond LLV gradient
- * Highest echo top located beyond LLV reflectivity gradient

What Happened?

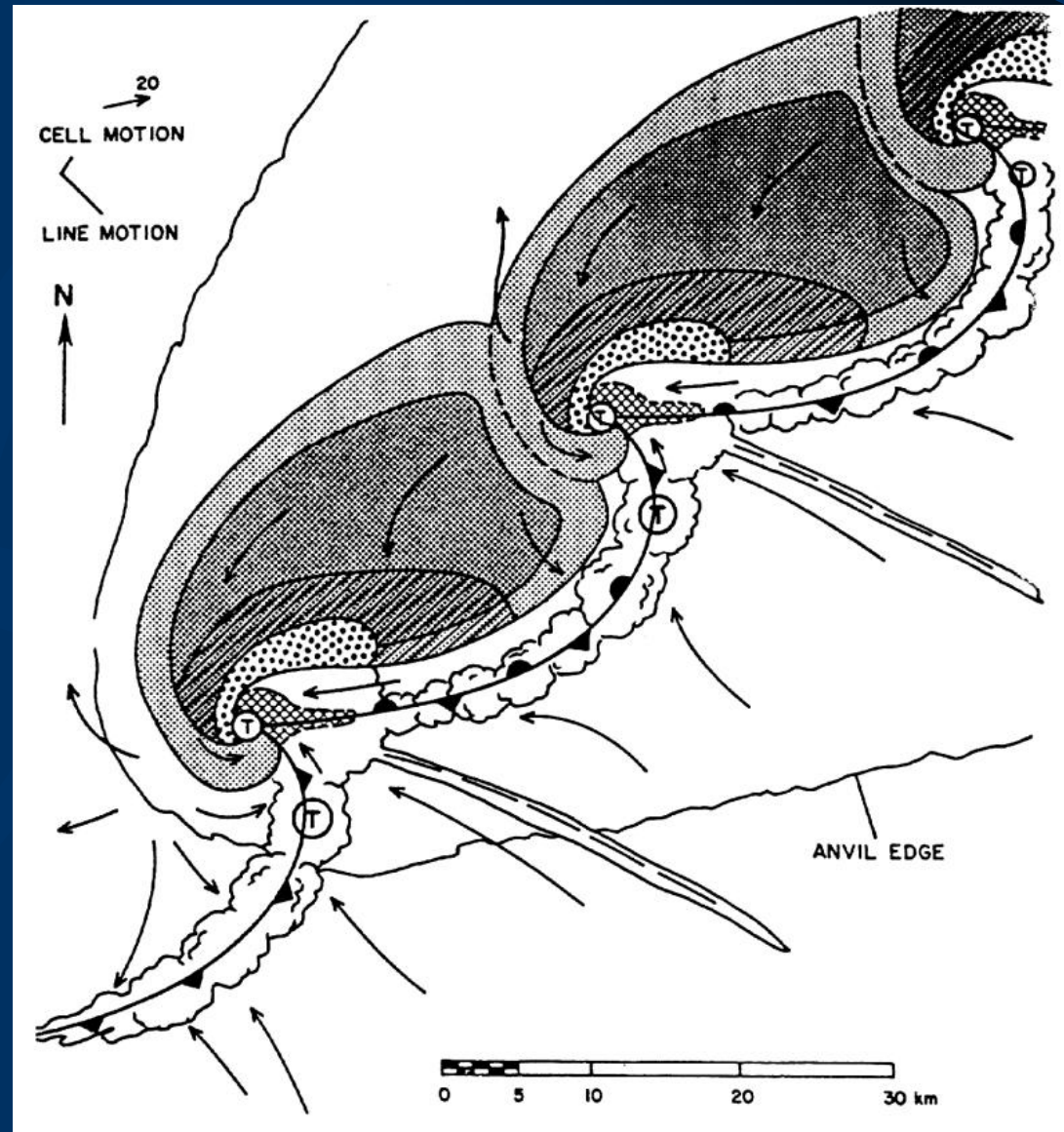


June 6, 1995 ~ 4:48 PM

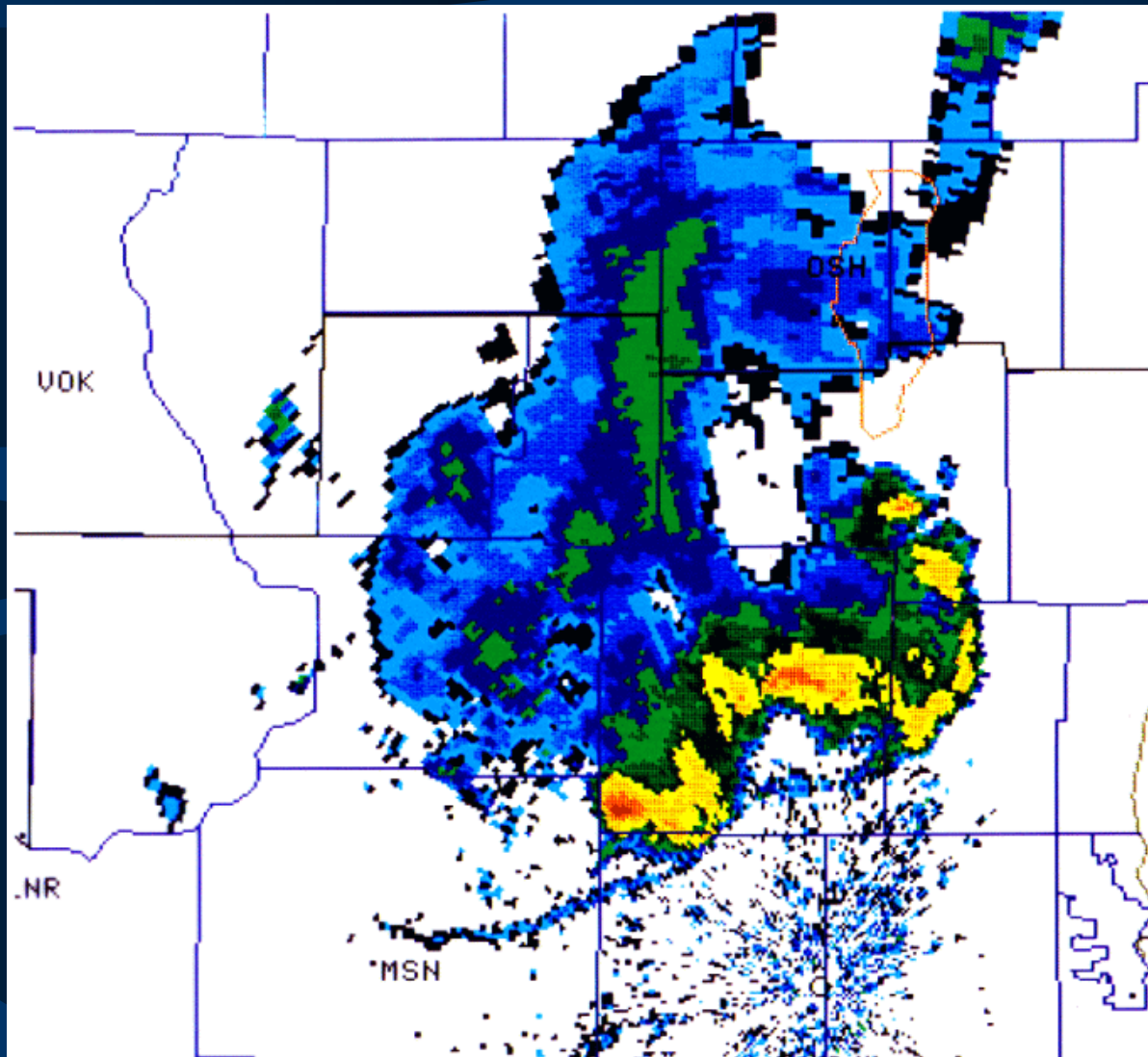
LEWP - Line Echo Wave Pattern



LEWPs may be a reflection of an intense mesoscale pressure system developing

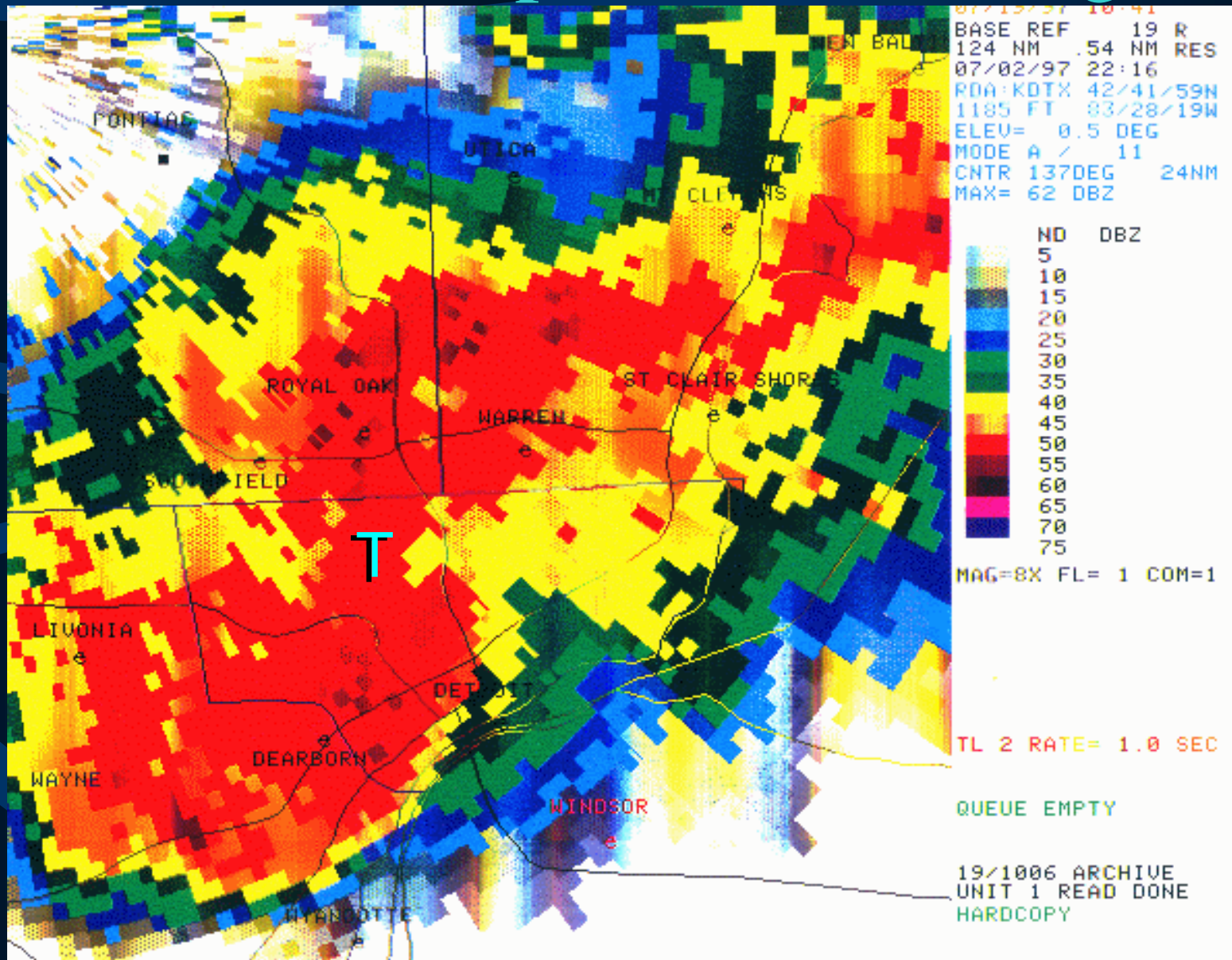


Multicell Line

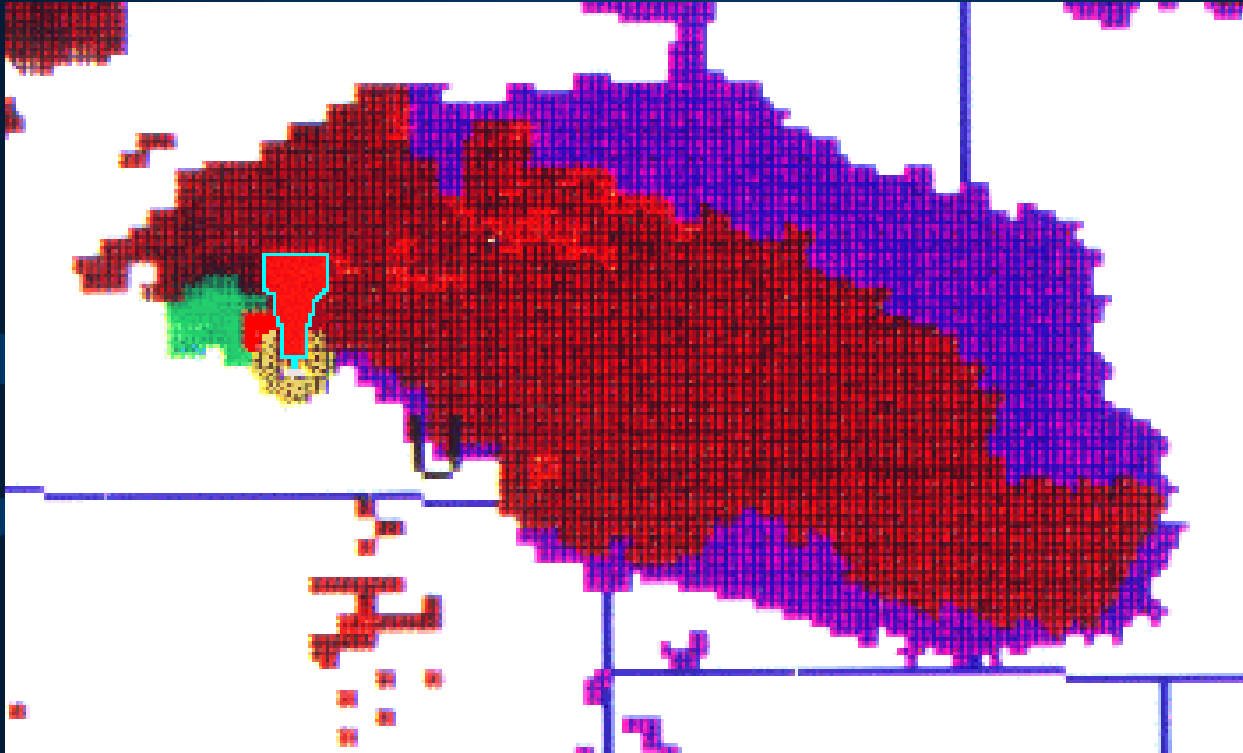


Intersecting outflow boundries

LEWP Example from Michigan



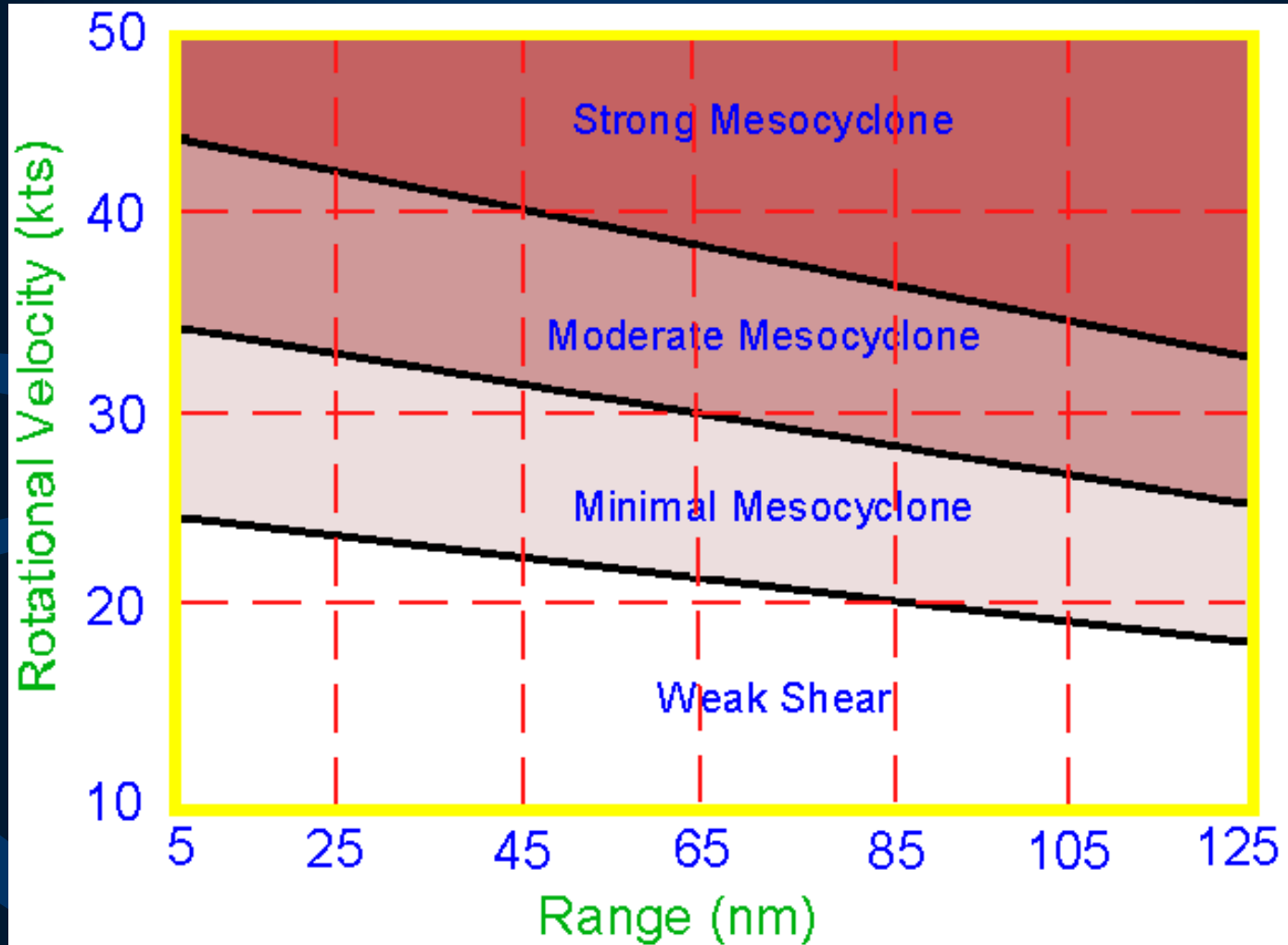
The Supercell



Oakfield, WI July 18, 1996 7:03PM

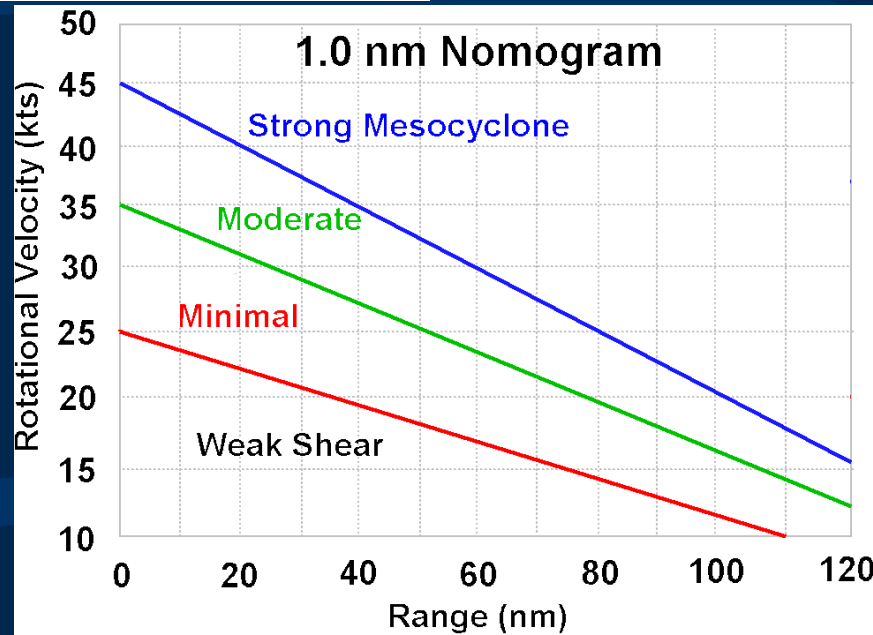
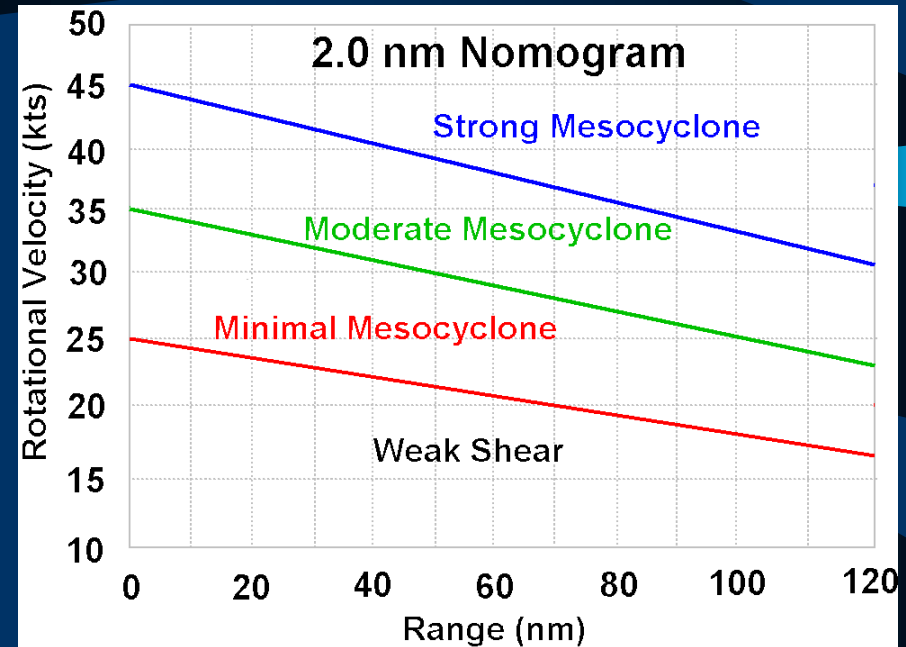
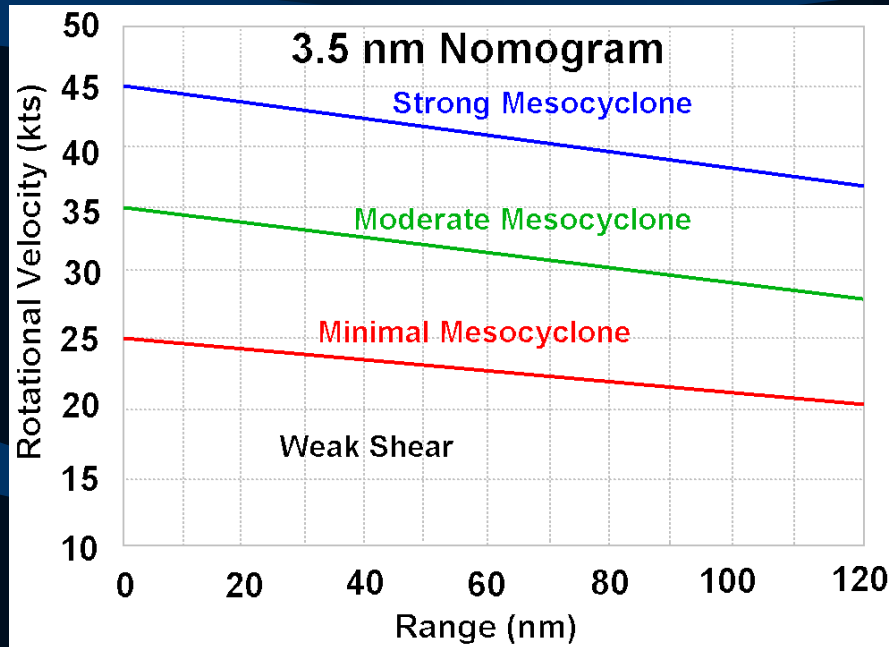
Mesocyclone Recognition Criteria

General Nomogram



$$\text{Rotational Velocity} = \text{Inbound} + \text{Outbound} / 2$$

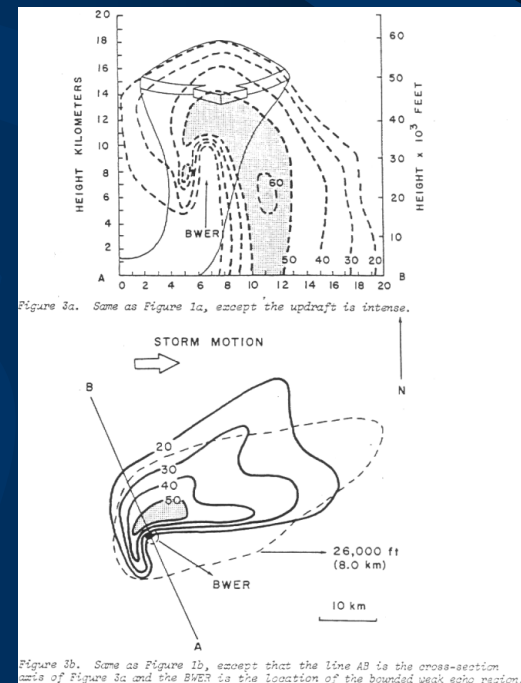
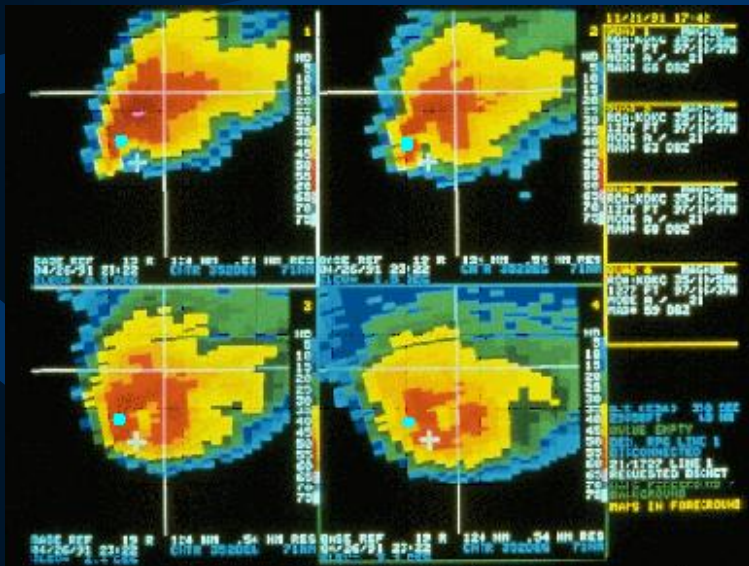
Mesocyclone Recognition Criteria



The Supercell

Some persistent characteristics found from storm to storm:

- An approximately circular to elliptic horizontal cross section aloft with a typical dimension of 11 to 22 nmi and a vertical extent of 40 to 60kft.
- At low levels, the echo is situated mainly on the storm's left flank and may exhibit a hook-shaped appendage that is located generally in the region of the rear flank downdraft.
- A persistent BWER found on the right flank. An RHI (cross-section) parallel to the inflow region will show this BWER the best.
- Will likely have a persistent meso-cyclone circulation. These will be hard to detect if the storm is LP or the circulation is too small (far away) for the radar to resolve.



Severe Storm Generalities

Les Lemon Technique - Tornado Warning Criteria Guidelines

Issue warning if:

All of the follow three are satisfied:

- Mid level (16-39kft AGL) return >45 dbz
- Mid level overhang > 3.2 nmi beyond the strong low level reflectivity gradient
- Highest echo top located over the strong low level reflectivity gradient, or shifted farther towards the mid level overhang.

And either or both of the following are present:

- Low level pendant i.e. hook is oriented at right angles to the storm motion. The pendant must lie beneath or bound the mid level overhang.
- A BWER is detected.

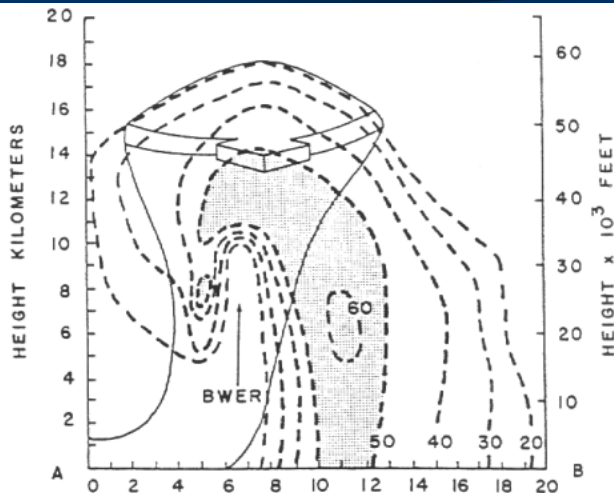


Figure 3a. Same as Figure 1a, except the updraft is intense.

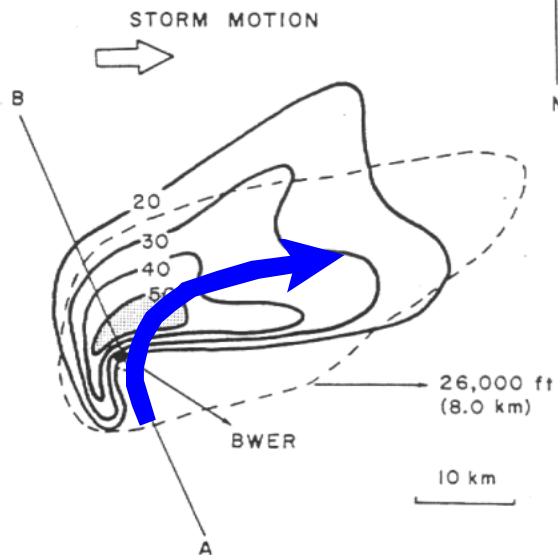
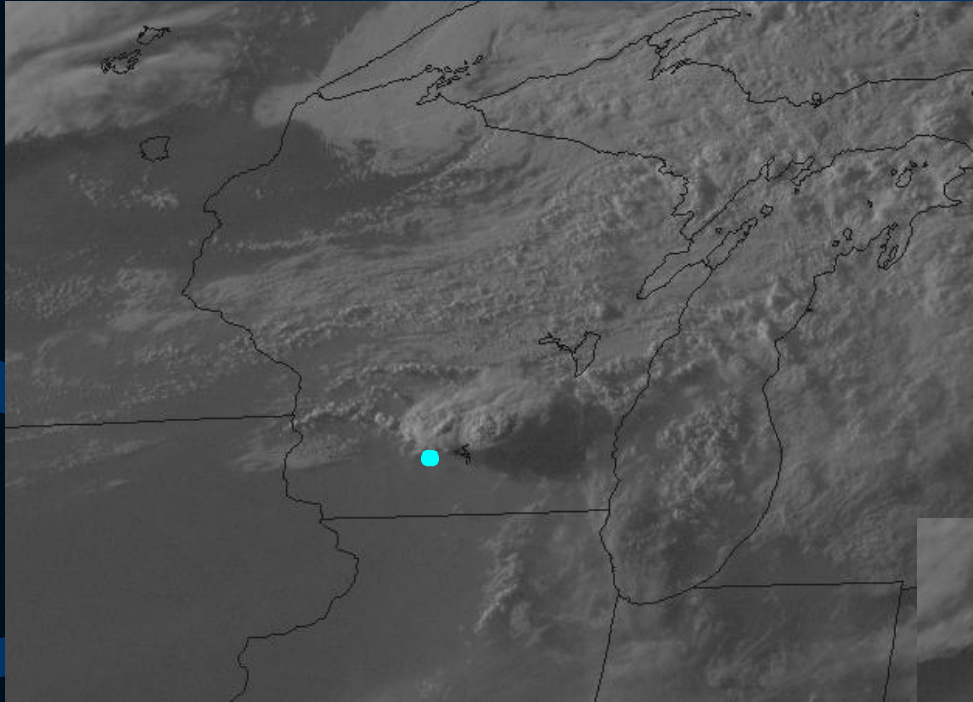


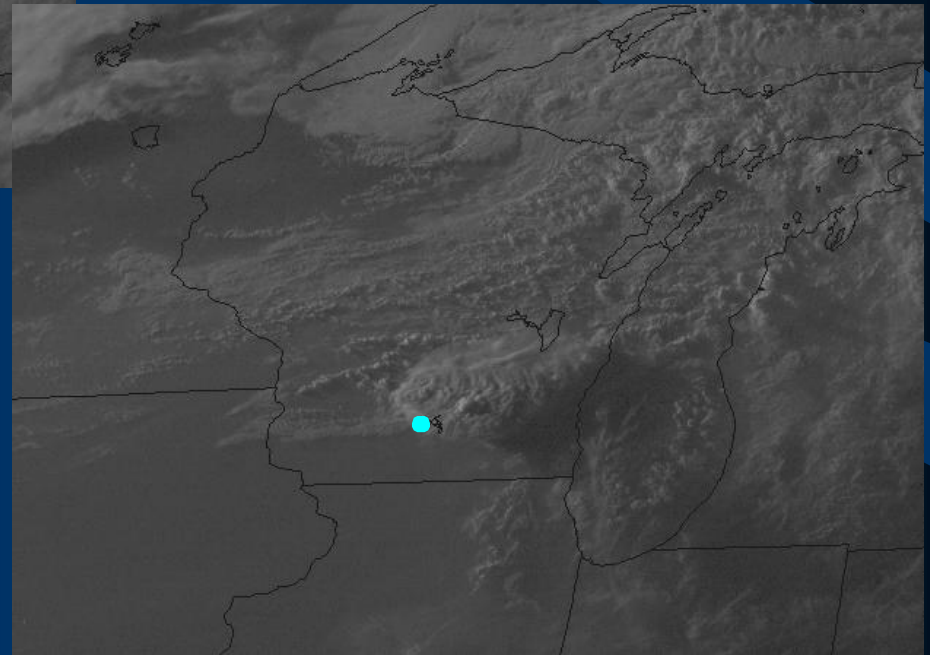
Figure 3b. Same as Figure 1b, except that the line AB is the cross-section axis of Figure 3a and the BWER is the location of the bounded weak echo region.

Dane County Supercell

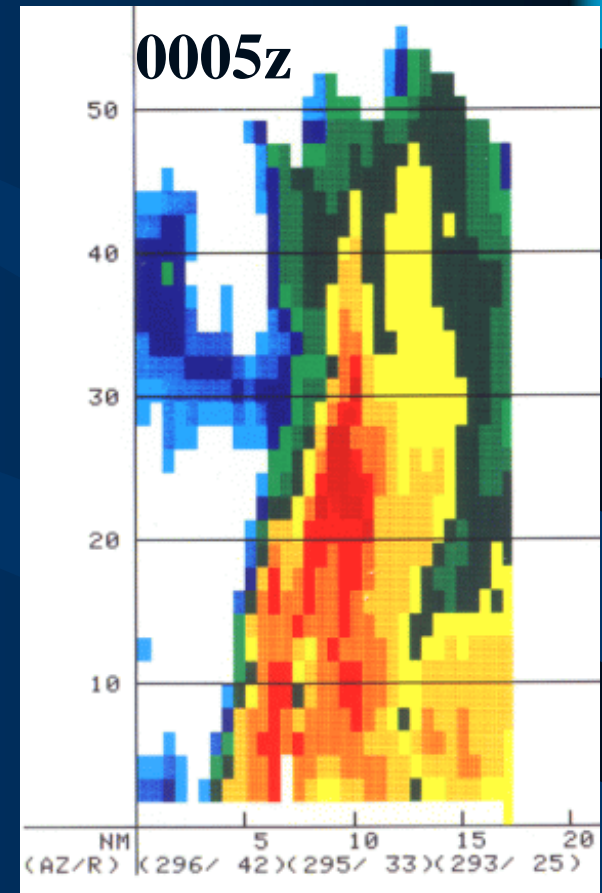
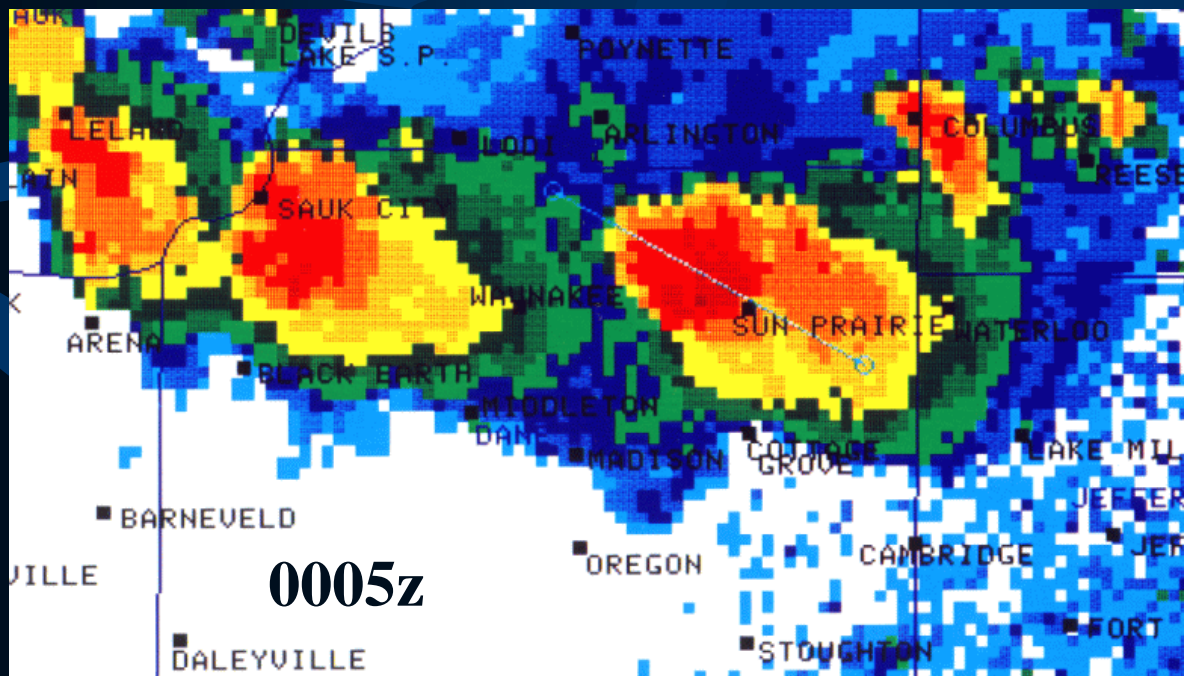
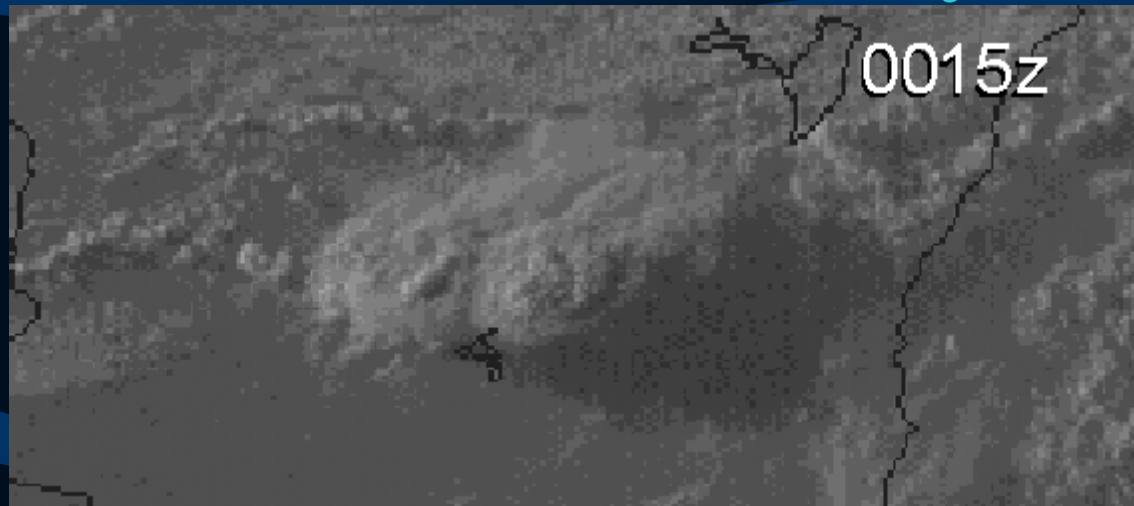
July 25, 1997



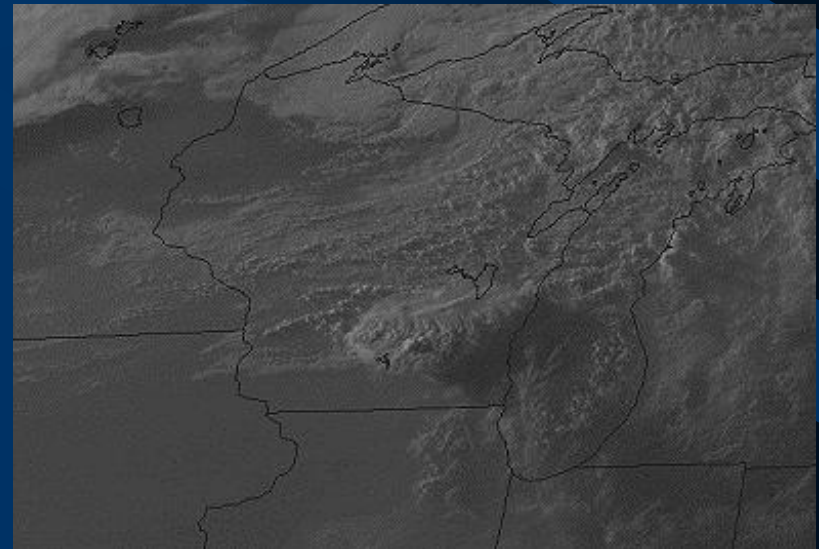
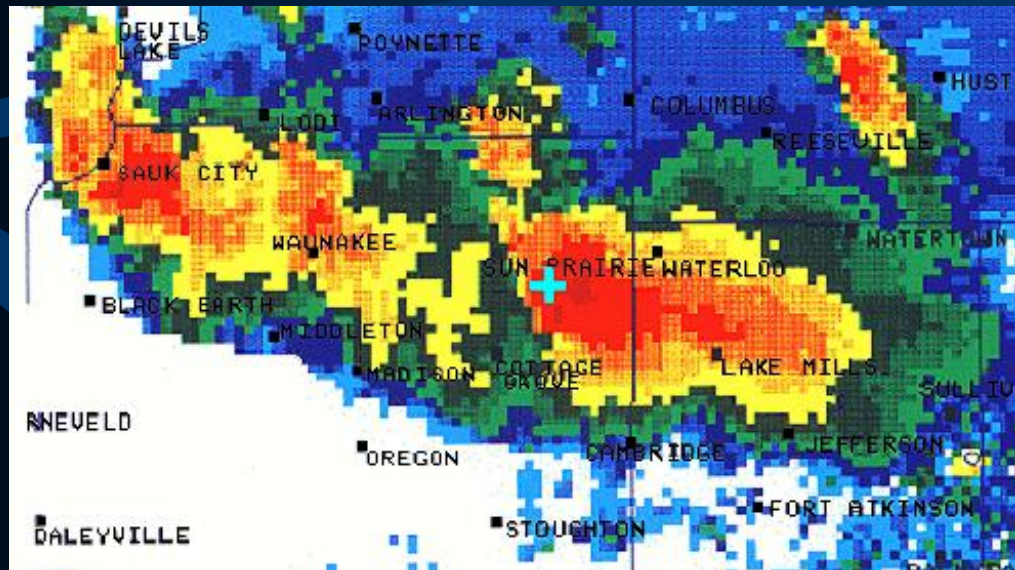
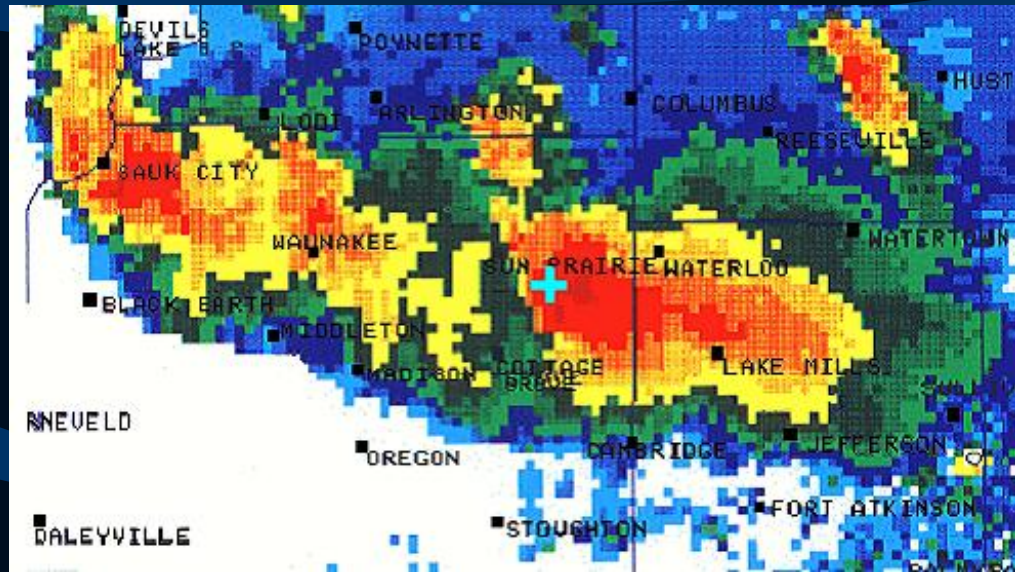
Tornado reported around
0040z northeast of MSN.



Dane County Supercell



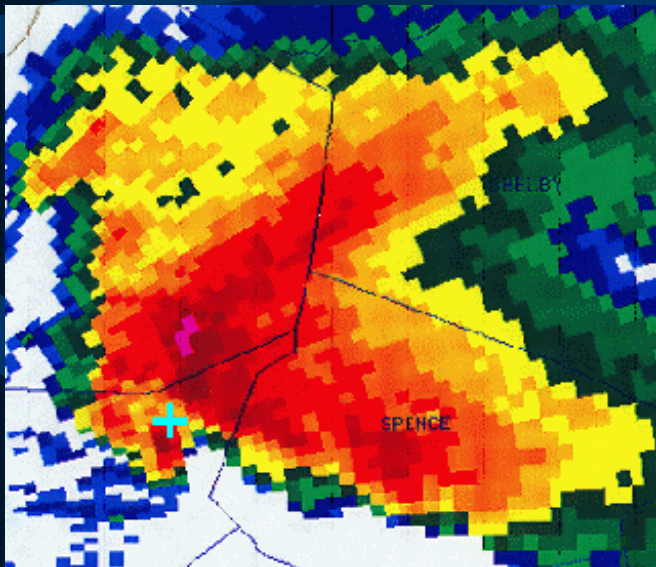
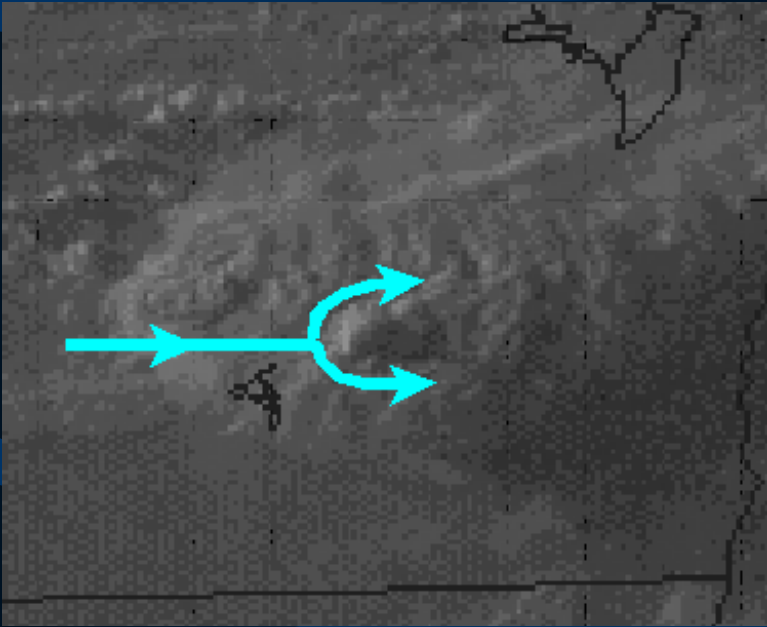
Dane County Supercell



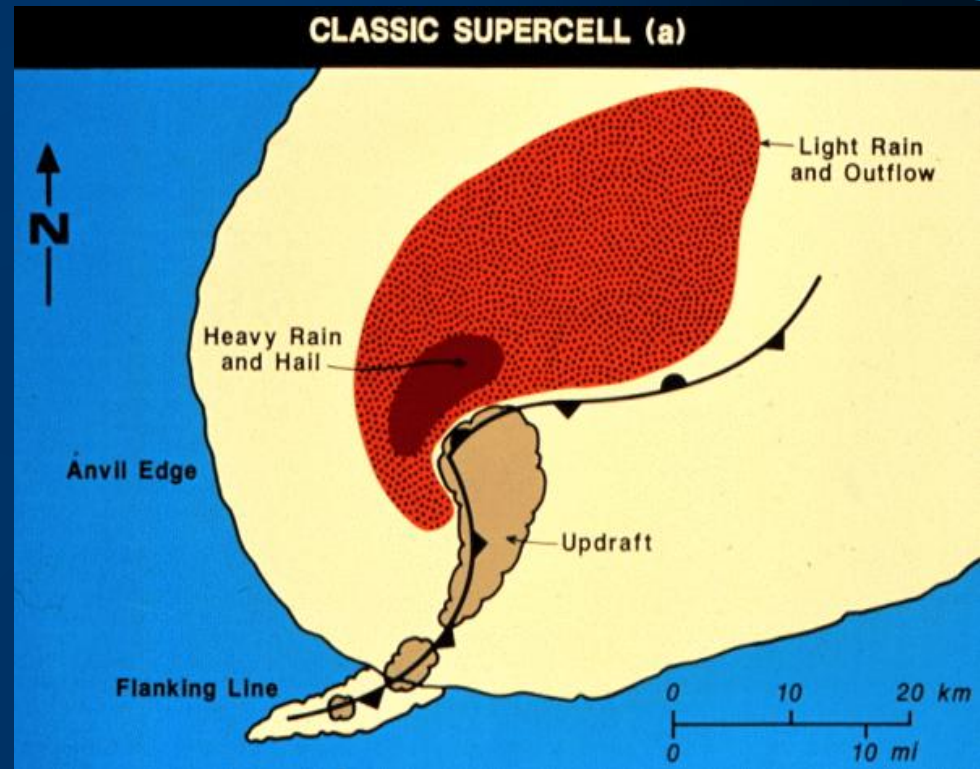
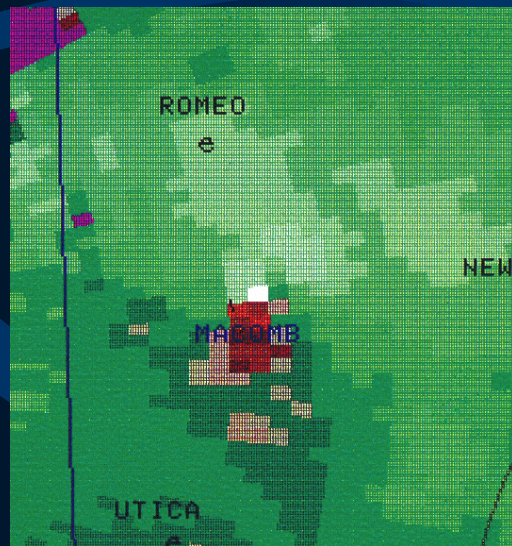
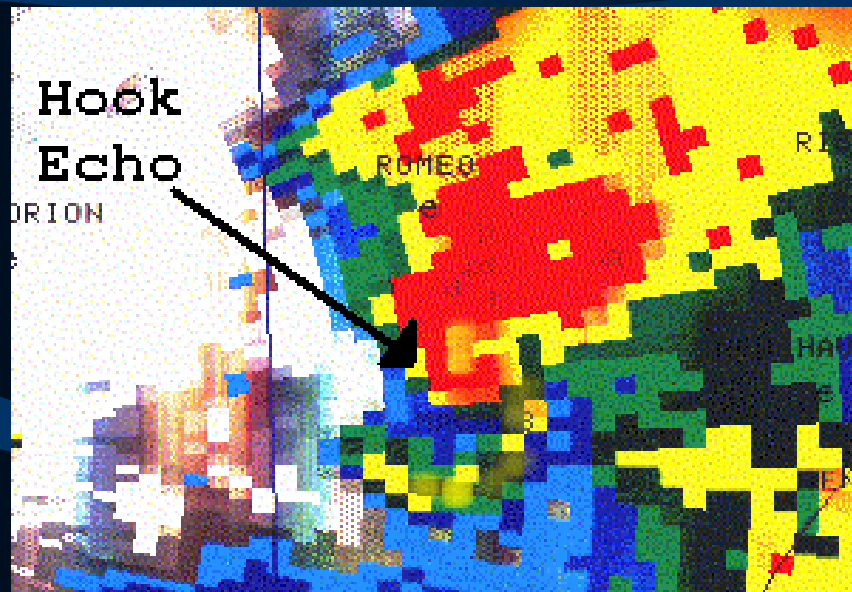
Supercell - The V Notch

A good indicator of Intensity/dynamics

Theory explains this as the mid/upper level winds encounter storm core and are diverted around it's mass.



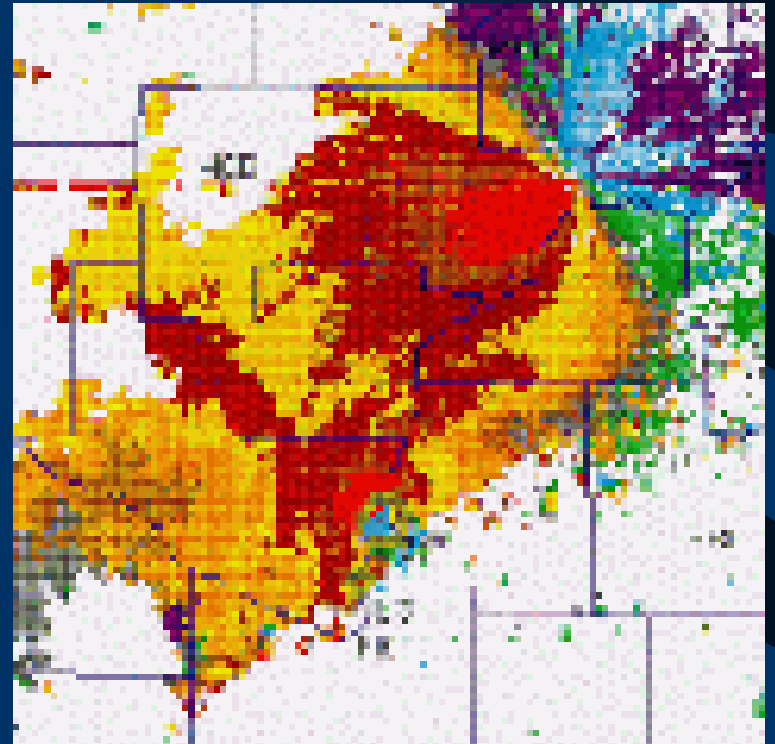
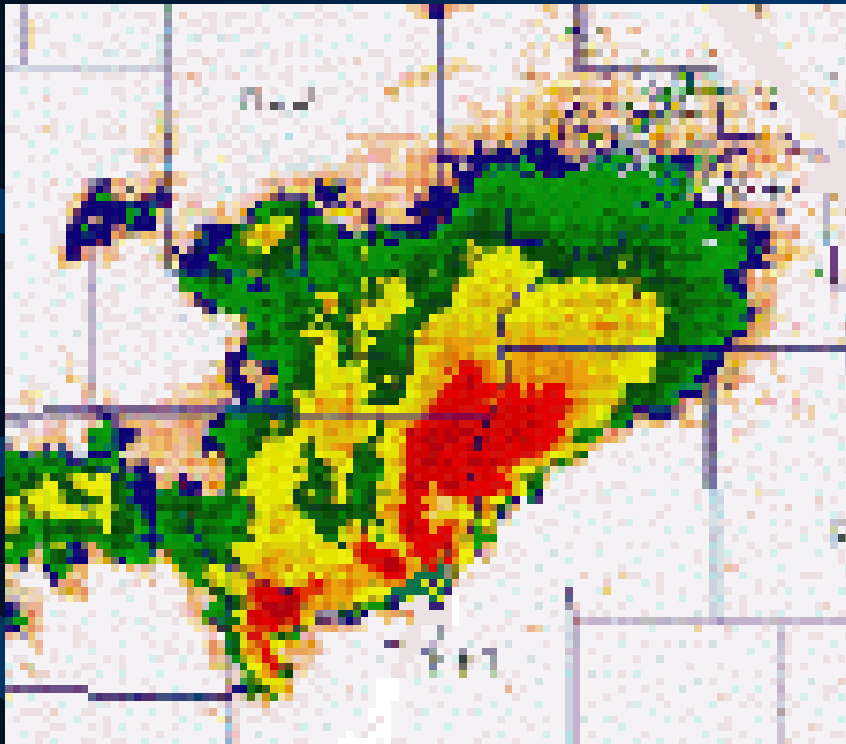
Supercell - The Hook/Flanking Line



Tornadoes in Michigan

Supercell in Minnesota

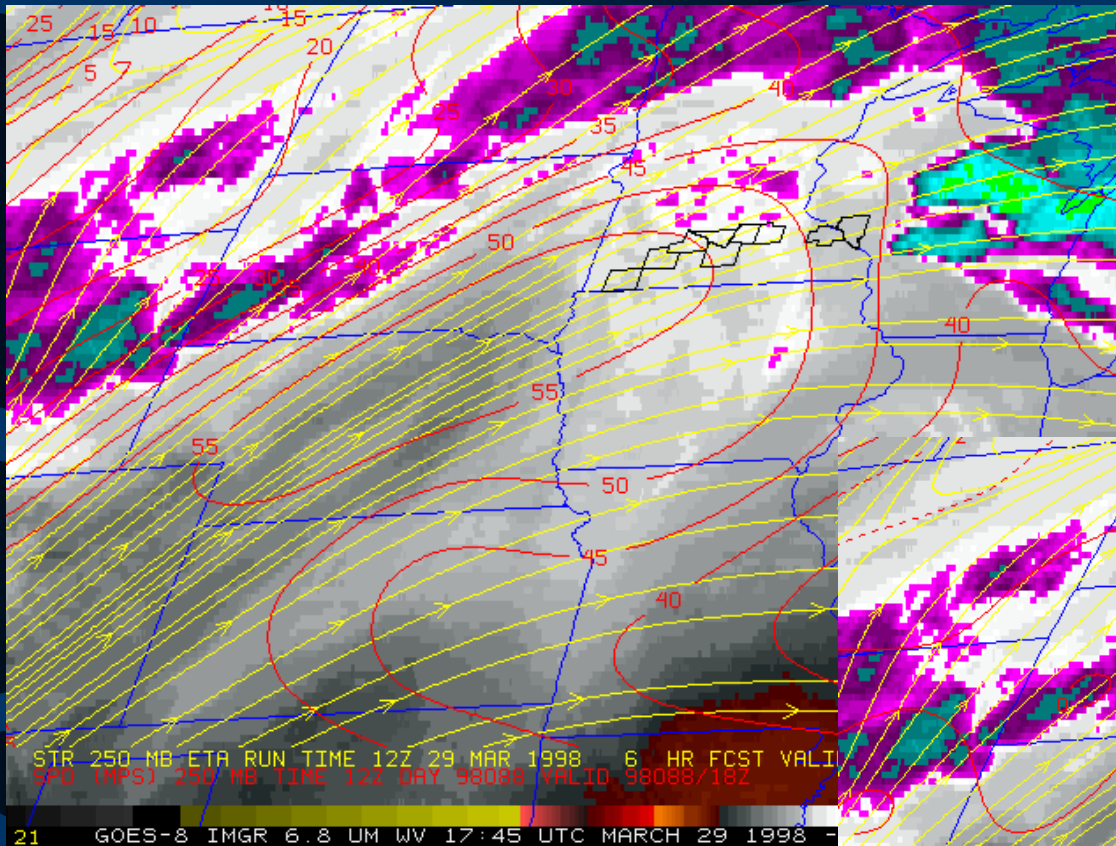
March 29, 1998. 13 tornadoes this day... beginning around 3:00 PM and continuing into the early evening.



The Environment...

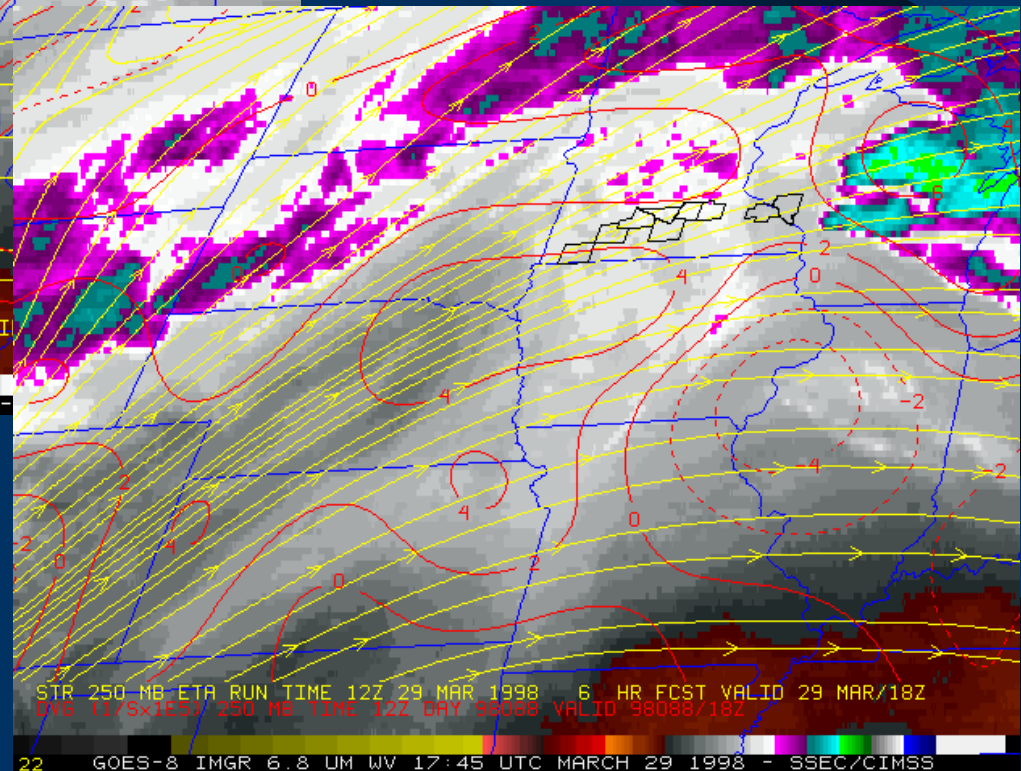


Minnesota Supercell Environment

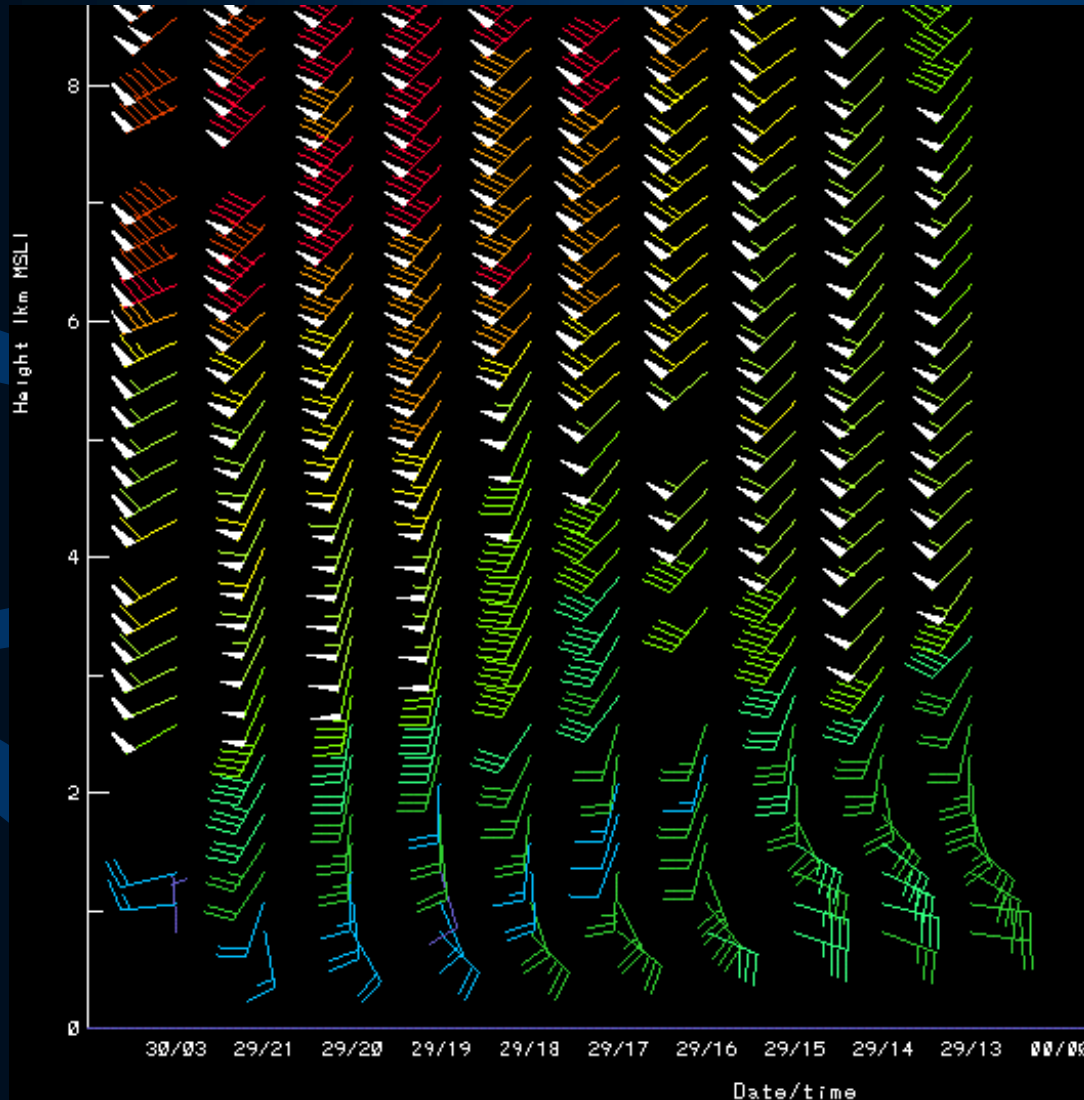


Upper Level
250mb Isotachs (m/s) and
Divergence

Valid March 29, 1998, 18z



Minnesota Supercell Environment



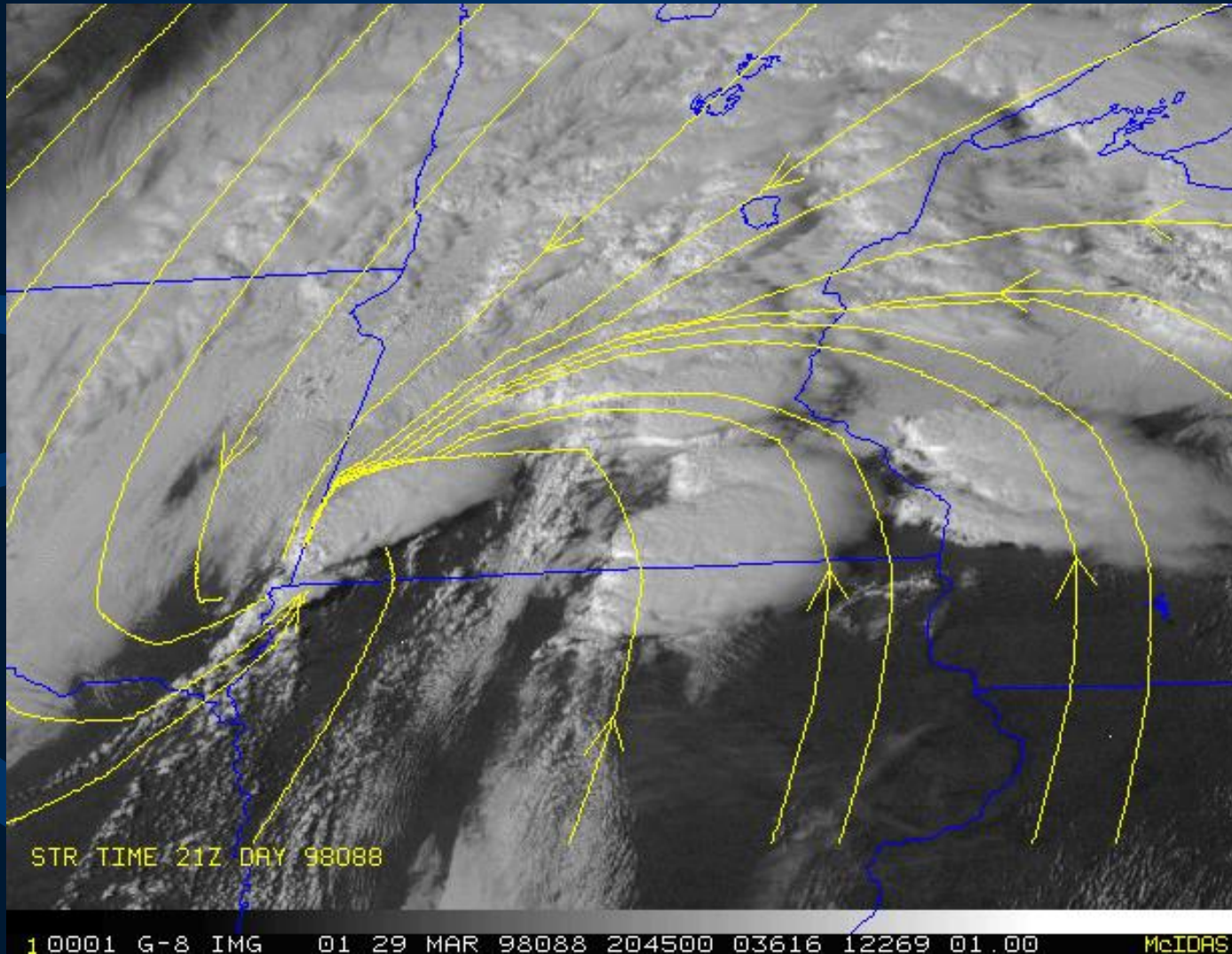
Wood Lake, MN profiler showing significant shear in the lowest 3-6 km.

Remember...

Supercells seem to be the favored mode of convection when the low-level, storm relative winds are greater than 19 knots and veer by roughly 90° in the lowest 4 km.

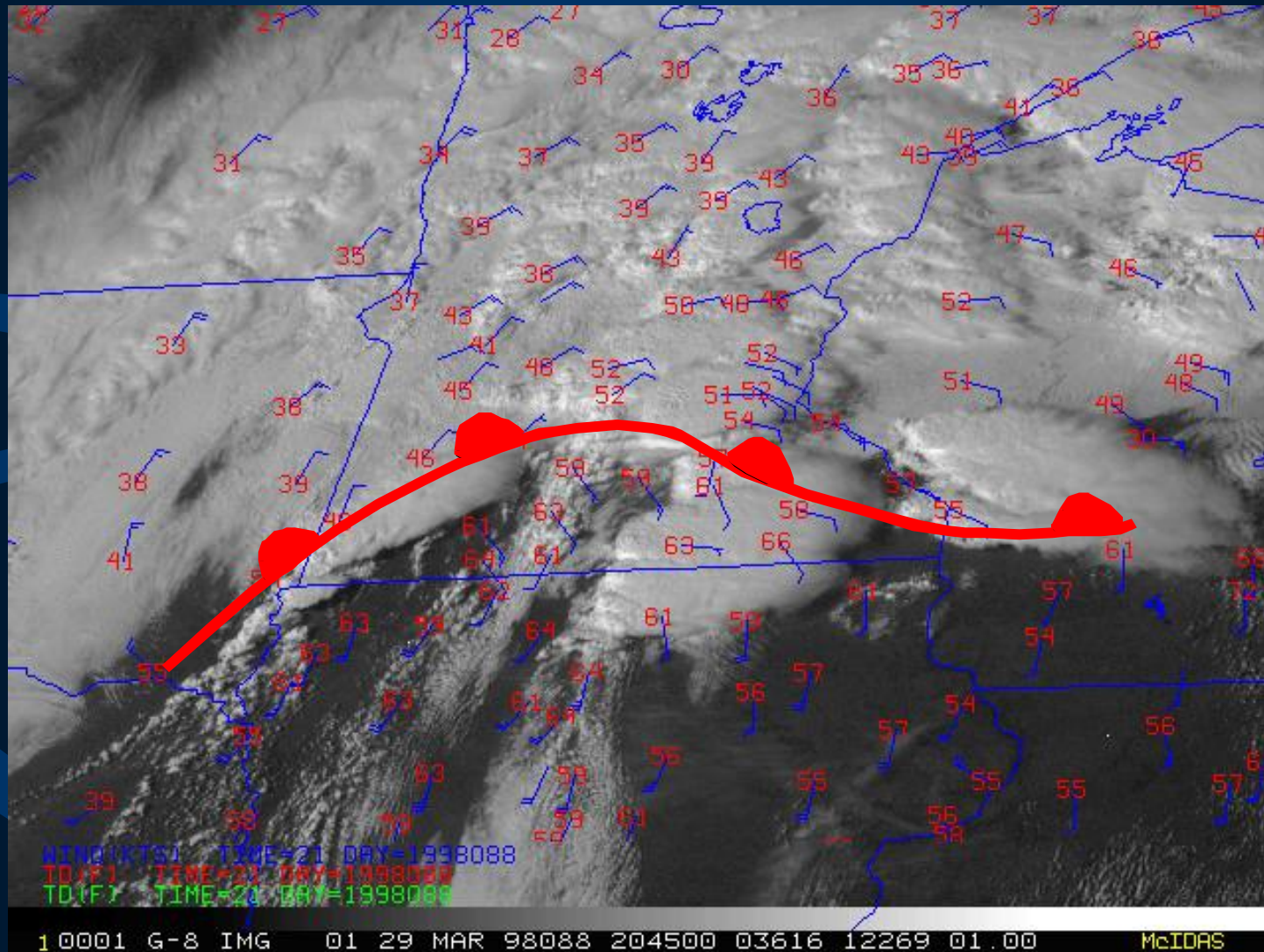
Minnesota Supercell Environment

Visible image and Surface Streamlines at 3:45 PM



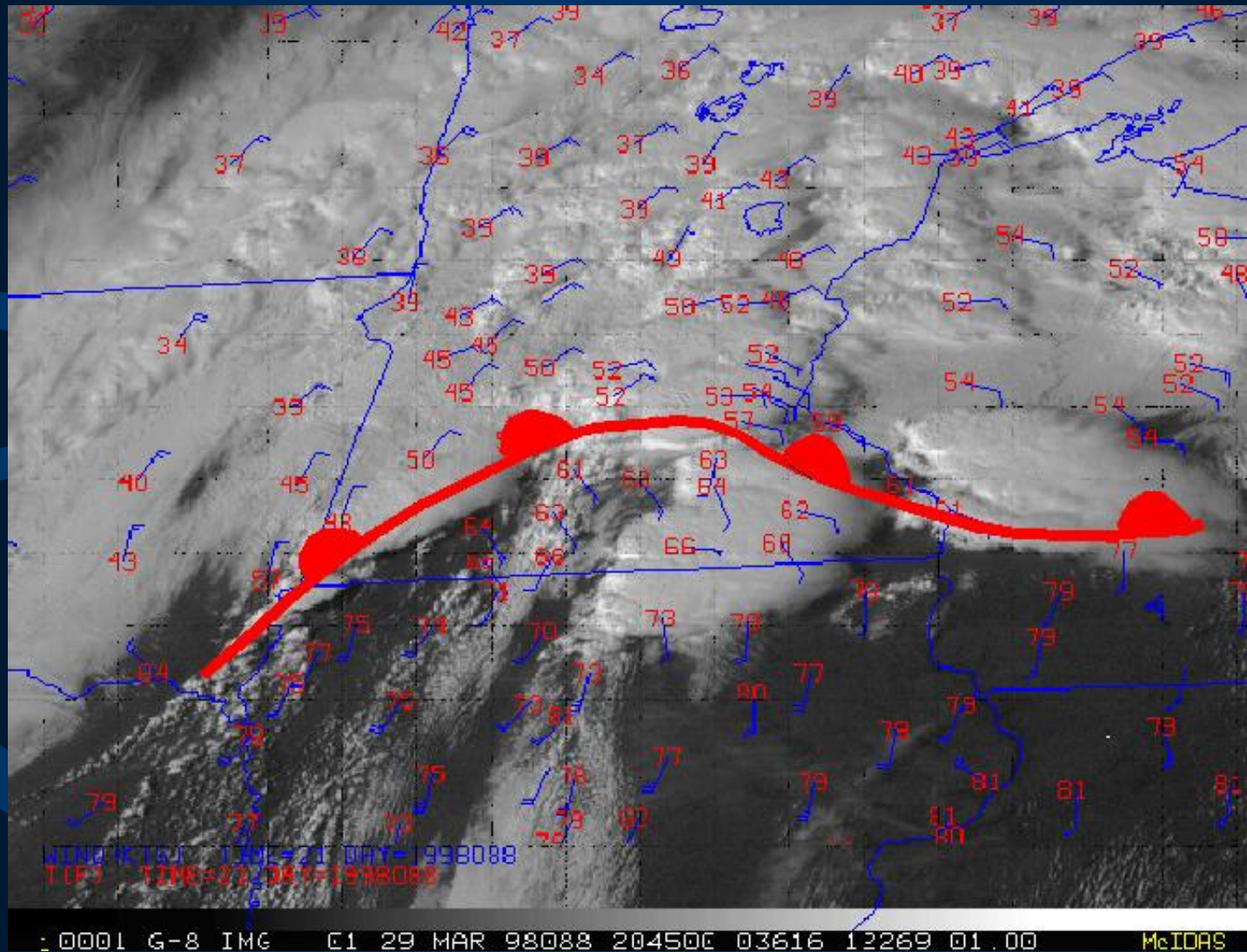
Minnesota Supercell Environment

Surface Dewpoints ($^{\circ}\text{F}$)



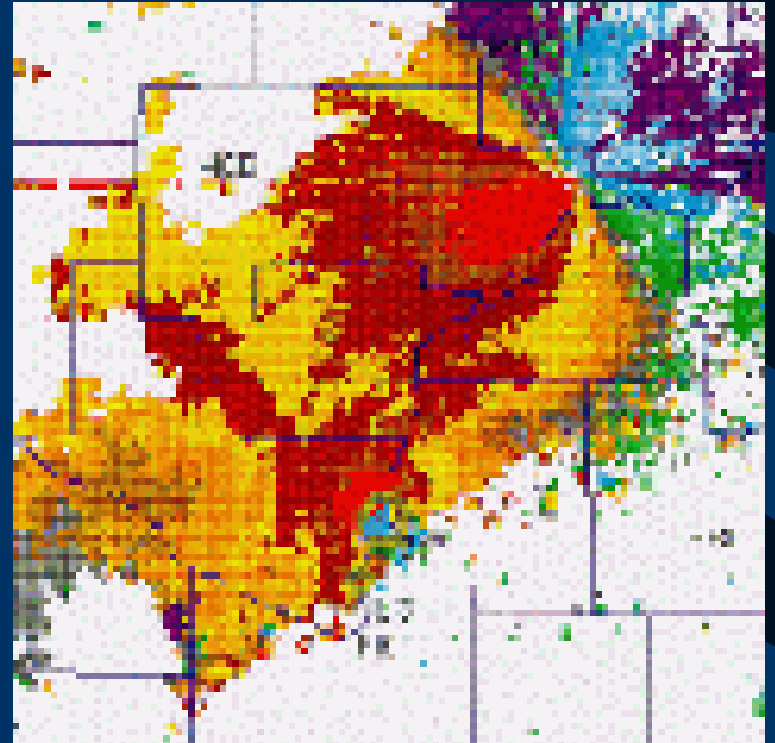
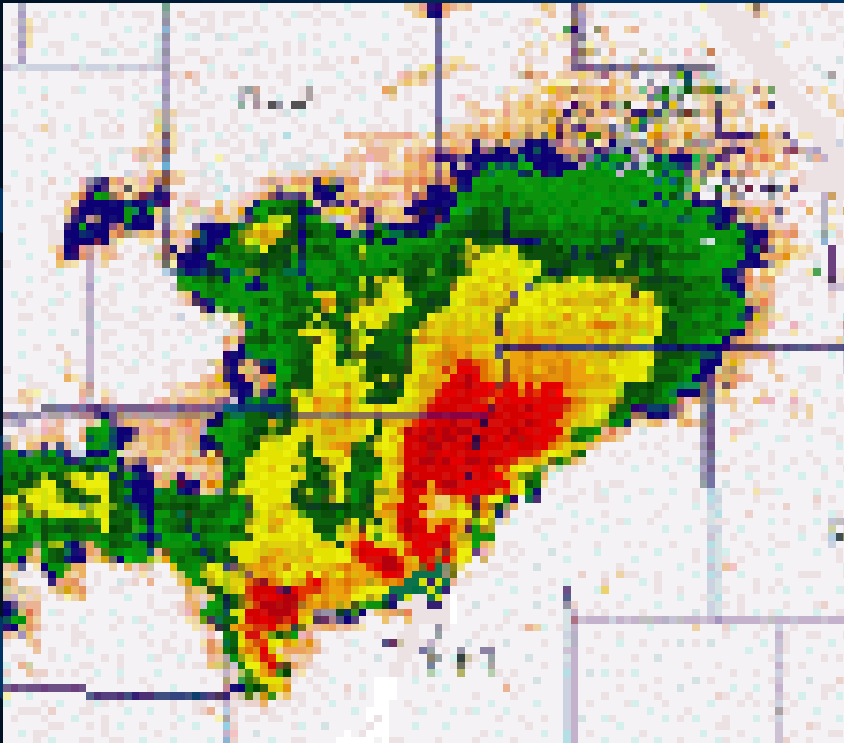
Minnesota Supercell Environment

Surface Temps ($^{\circ}\text{F}$)



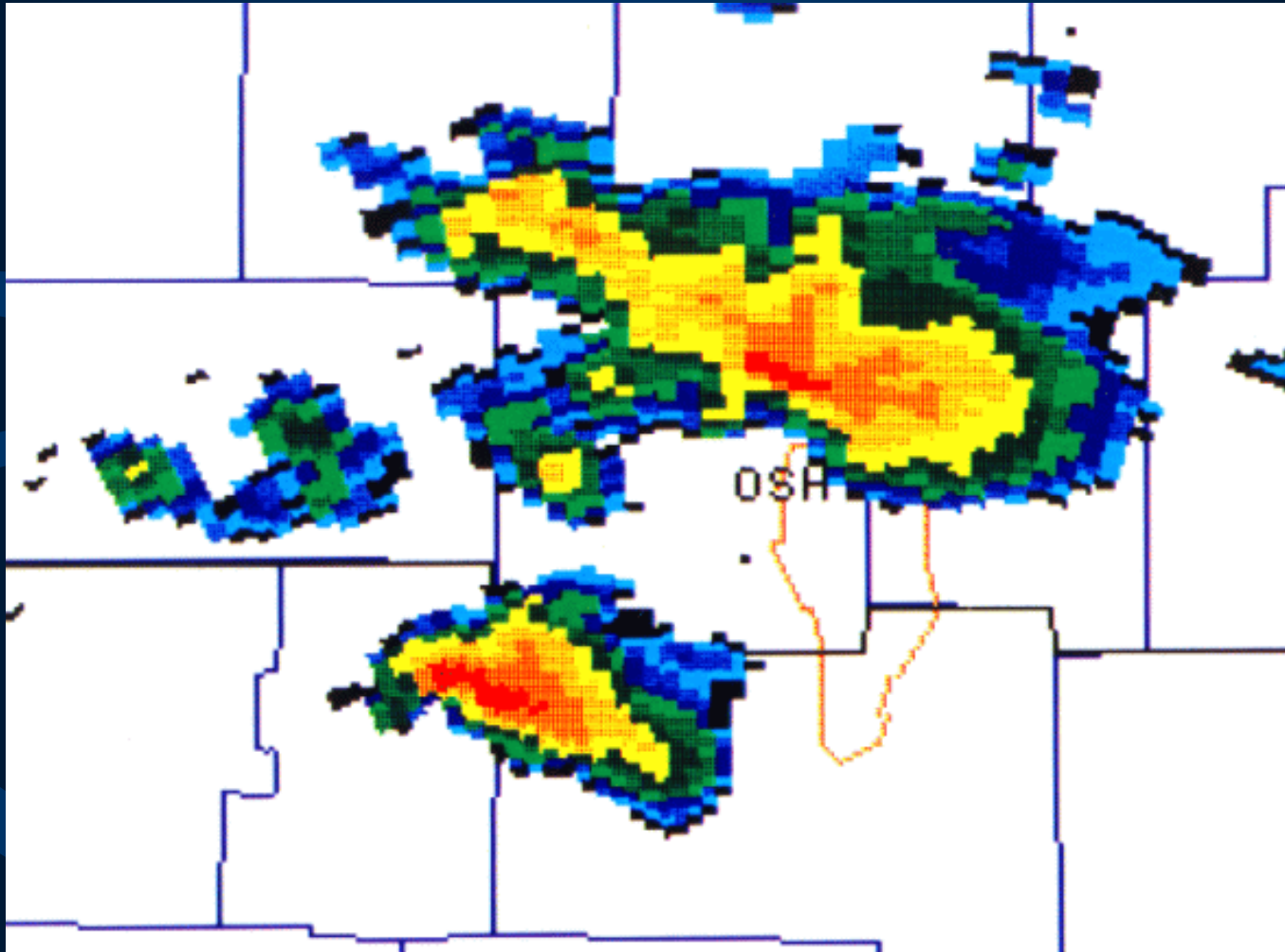
Supercell in Minnesota

March 29, 1998. 13 tornadoes this day... beginning around 3:00 PM and continuing into the early evening.



The Oakfield Tornado

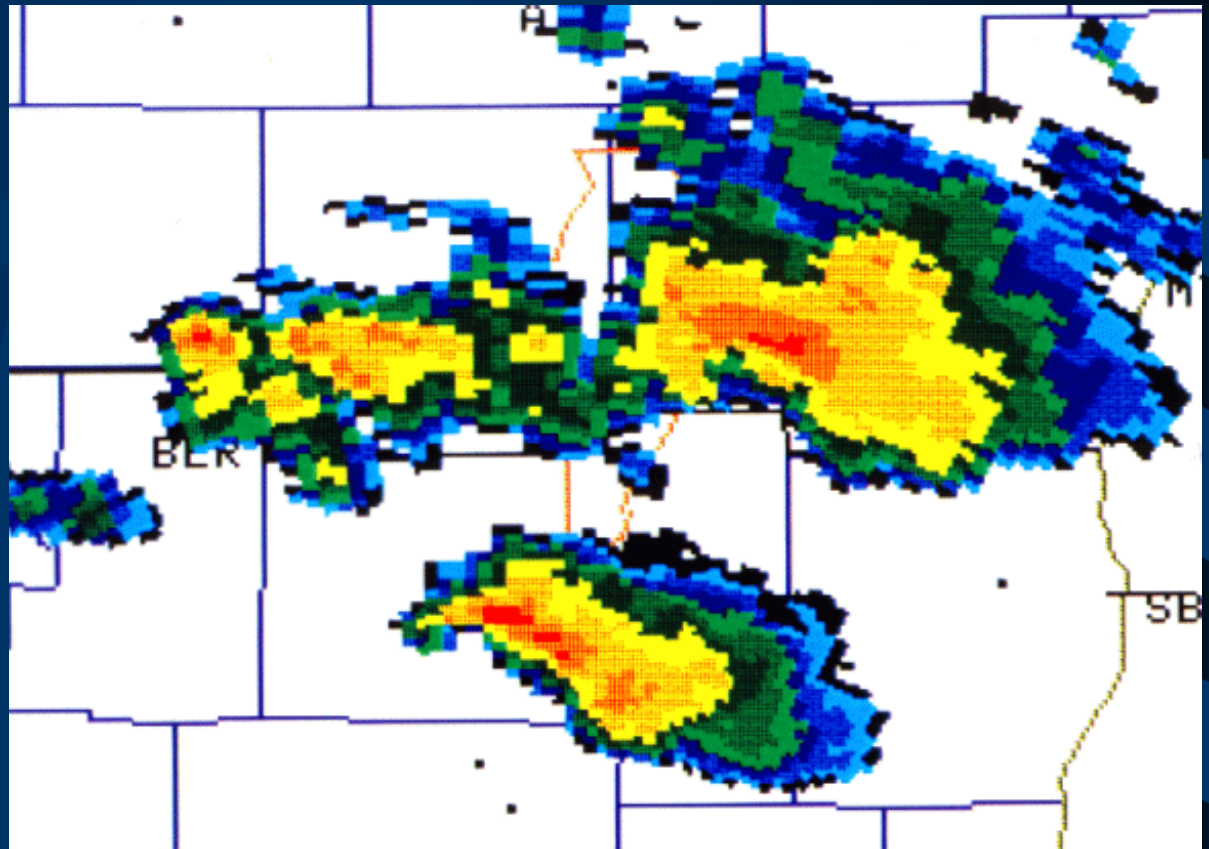
Reflectivity 2328Z



The Oakfield Tornado

Reflectivity 0003Z

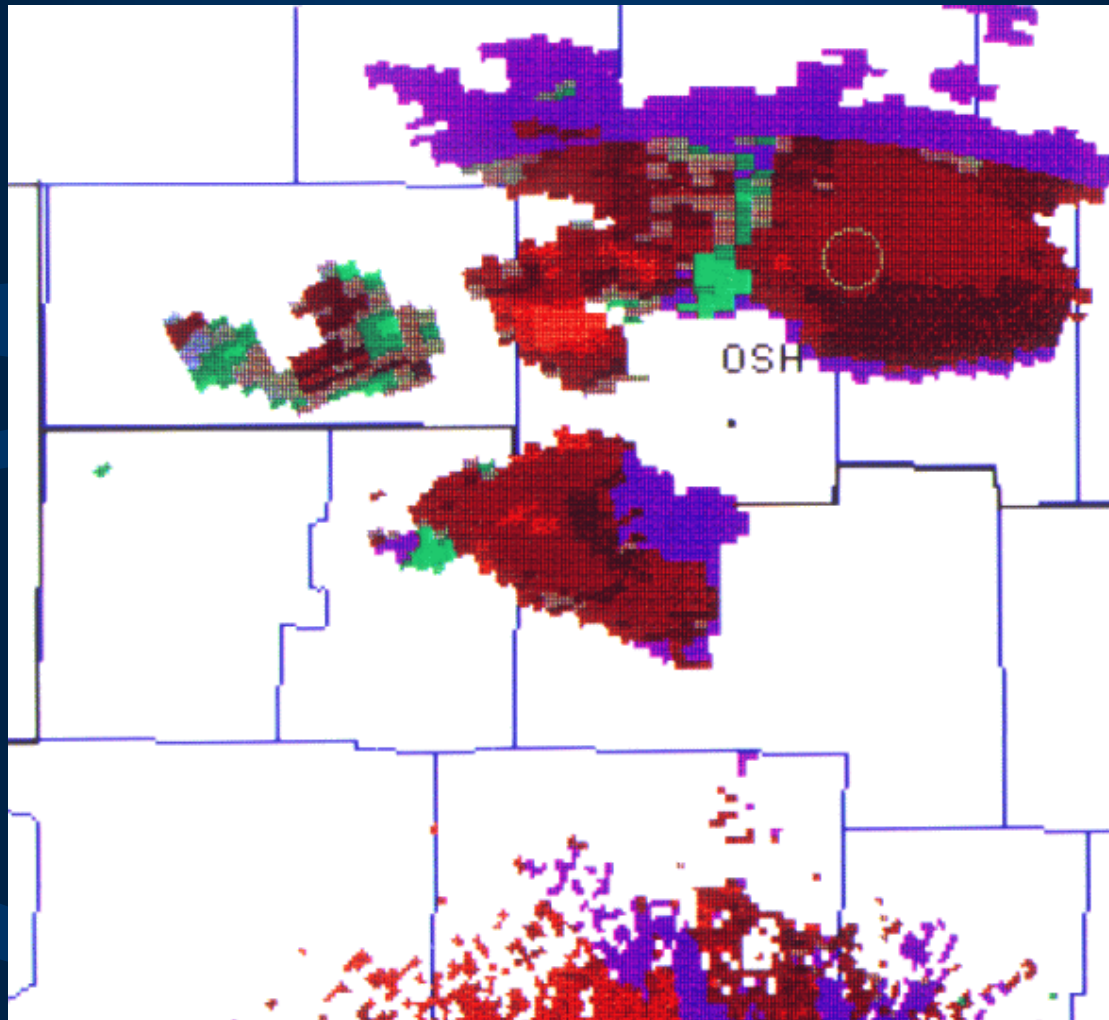
Pendent, or hook echo,
on right rear flank.



The Oakfield Tornado

Storm Relative Velocity

2328Z

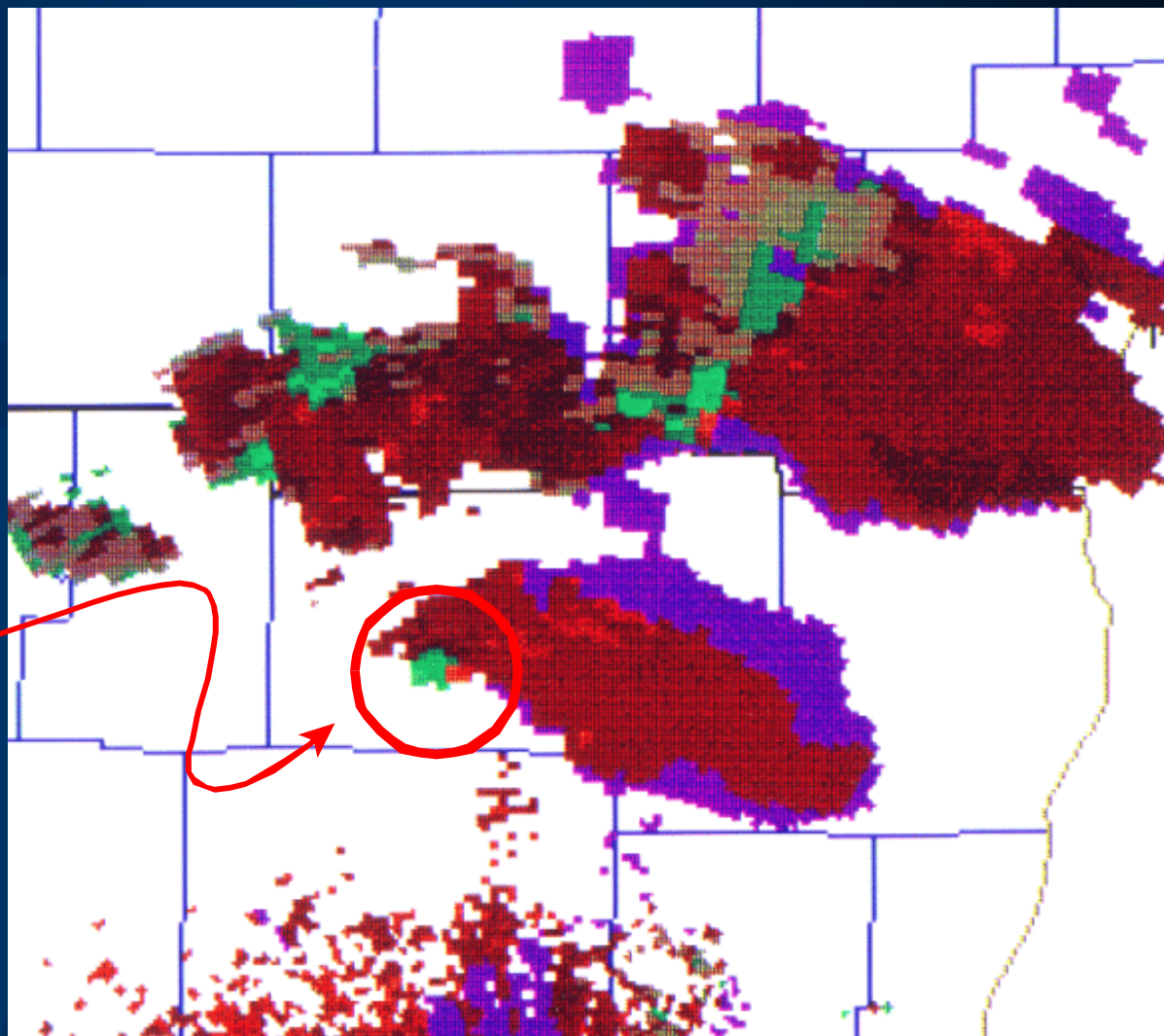


The Oakfield Tornado

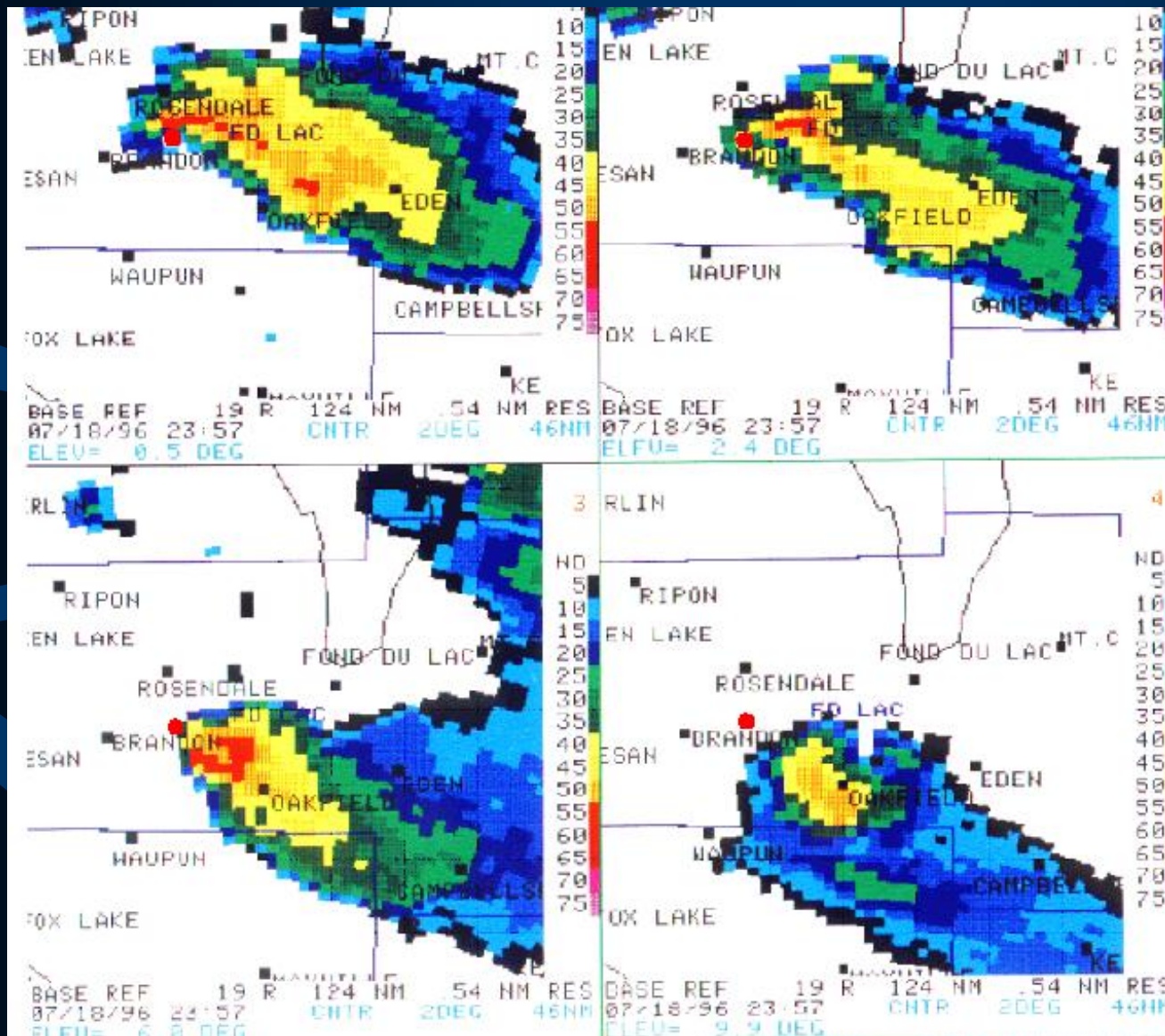
Storm Relative Velocity

0003Z

Classic rotational couplet. **Green** is inbound and **red** outbound...relative to the radar which is south of the image

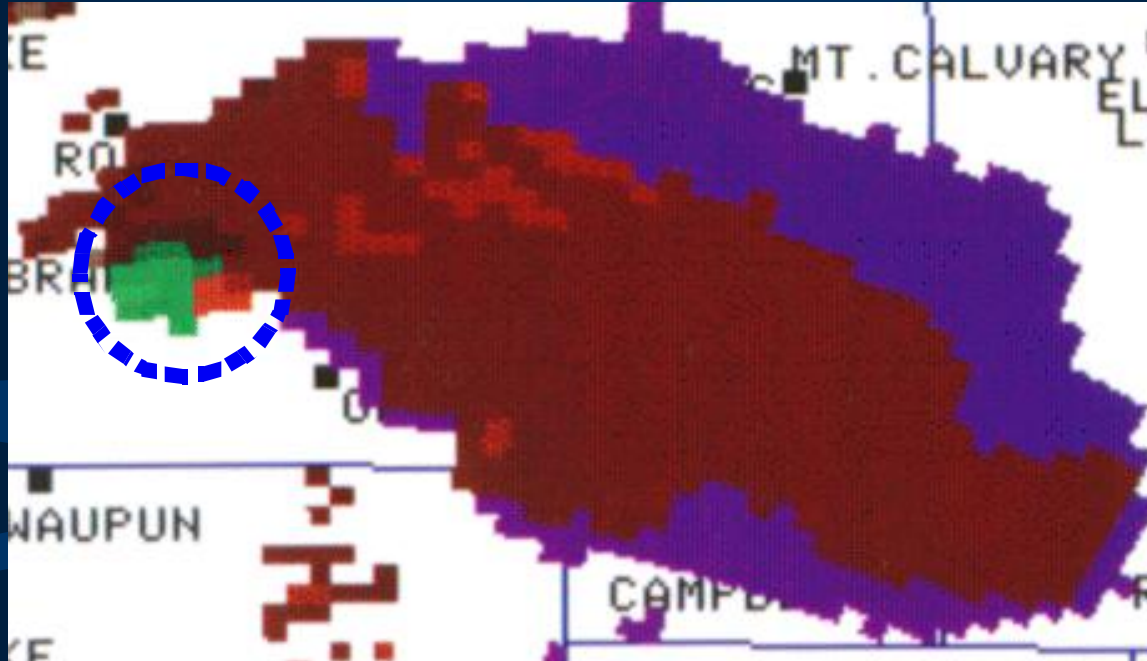


The Oakfield Tornado



4-panel display
showing overhang
and BWER at
23:57z

The Oakfield Tornado



Oakfield F5 tornado. July 18, 1996.

On the ground from 7:05 PM - 7:35 PM

No deaths

12 injuries

\$39.5 Million in damage

End of Part II